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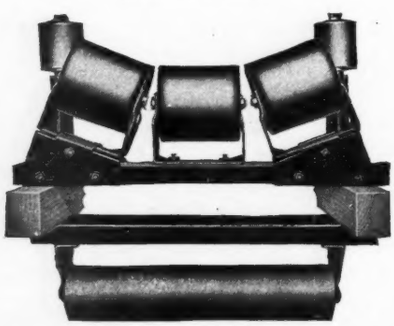

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Engineering and Mining Journal

VOLUME 102 JULY 1, 1916 NUMBER 1

Choosing the Mill Site

By Edward S. Wiard*

SYNOPSIS—The selection of a mill site is usually governed by local considerations that do not leave much room for choice. The facility for securing water, mill supplies and power near the mine have to be considered, and after these the character of the site itself may be discussed.

This problem of the mill site is usually in the form of flat versus sloping site, but before determining the exact spot for the mill, a small area in which it must be placed is the principal factor, and of the others some local one will often be determining. The question of a proper water supply is usually of paramount importance and becomes increasingly so as the upper limit of size to which the ore is crushed increases. If jigs are employed, a large consumption of water is indicated, particularly if the jigging be of the kind making tailings as well as concentrates and middlings, for with the usual way of disposal of tailings by sluicing a large volume of water will be necessary. It is of course feasible to dewater the jig tailings, using the water so obtained for washing purposes and removing the dewatered tailings by means of conveyors, but a metallurgical engineer would consider such a procedure only in the event that the other factors far outweighed the water facto. and water was extremely costly to obtain.

The tendency of concentration schemes is toward finer preliminary reduction in size, and this tendency is making for simpler mill plans with fewer machinery platforms or terraces. In times past in lead-zinc jig mills any lead concentrate carrying less than 8 to 10% zinc, depending upon the point at which penalizing began, was acceptable, even in camps where it was possible to make a salable zinc concentrate. At the present day, with the better means of saving the concentrates in slimes provided by the flotation processes, the use of the Harz jig, the Hancock jig and the concentrating table as roughing devices is becoming more common. When these machines are used for roughing, as much of the heavy product is removed by them as is possible, the balance of the material fed to them being reground for treatment in a fine state of division. It means fewer screens or no screens, wider floors and a lower superstructure, and hence a foundation plan adapted to gently sloping or flat sites.

TIMBER BUTTE MILL, AT BUTTE. AN EXAMPLE OF AN INCLINED MILL SITE

The procedure of rigidly limiting the escape of water from a mill by repeated dewaterings originated in arid regions where water is a scarce and precious commodity. Where it is carried to the extreme, only such water escapes as is sufficient to carry away sand and slime tailings. If the sand and slime be routed to a settling pond, the overflow of this pond being used over again for wash water, the loss is confined to leakage from the pond dam and the small amount lost through evaporation.

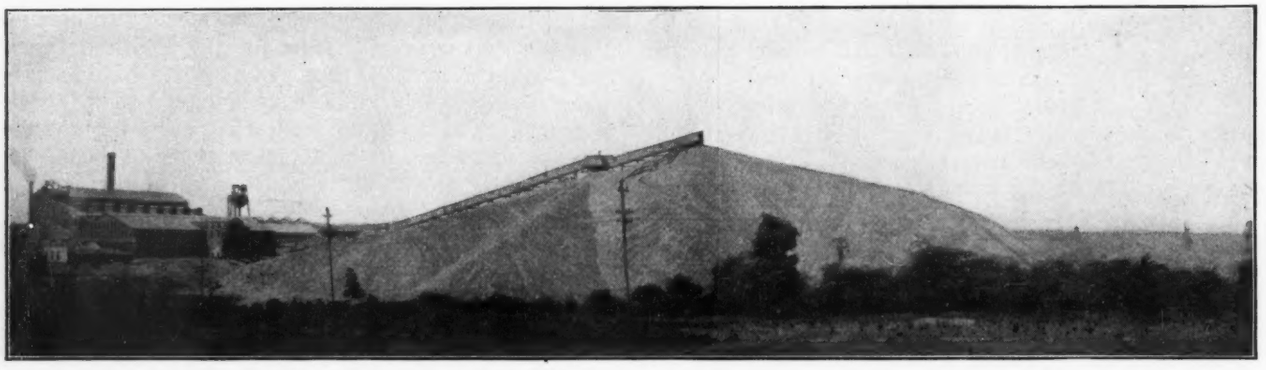
*Mining and metallurgical engineer, Denver, Colo.

Unless economy in the use of water is imperative, dewatering and settling should be carried only to the degree necessary for proper preparation for the treatment of products. The deliberate use of tank sludges as wash water is very bad practice if clean water is available. A common expedient in half-baked improvements, originated after the mill is completed, is to use slimy waters as wash water, these being deemed too good to throw away and yet not good enough to warrant special treatment other than by settling and use in the way mentioned. The disadvantages in the use of slimy water as wash water are many. It settles with difficulty, and the chance of any concentrate being saved from it is small. A relatively small amount of the slime adheres to the decks of sand and slime concentrators and alters the cling of the washing-up surface. To some extent the fouling of the washing surface can be overcome by brooming at regular intervals. Stoppages of the apertures of the wash-water boxes will occur where slimy water is used for washing and more particularly where the water box is not shaken with the table. Slimy wash water obscures the vision in controlling the separation of the high-grade products. This difficulty and the further one of the contamination of the concentrates by the slimy water can be somewhat overcome by the use of clean water sprays at the point where the concentrates discharge.

Where water is used over and over again, there will often arise further difficulties. If there is present free acid or an acid radical capable of attacking iron or steel, as there is in sulphide copper ores, there will be an upbuilding of the acid content of the wash water. If there be salts present in the wash water which precipitate on being oxidized by long contact with the air, a nasty muck will form, which in the case of iron salts yields a deleterious and strongly adhering coat on linoleum surfaces.

There is a vast difference in the settling power of clean wash waters, and my experience has been that such differences are largely inherent in the water, though the ore itself often affects the rate of settlement. As a rule the purer the water the better it is for concentrating purposes. In our northern camps the purest water is nearest to the snow line, but anywhere in the mountains proper, uncontaminated water suitable for concentrating purposes will readily be found.

If it is proposed to have the mill near the mine and the mine is in the upper part of the mountains and at an early stage in its development, the following difficulties will be encountered: The ground will probably be too precipitous to provide a good natural site, and such excavations as have to be made will largely be in solid rock. The supply of water will scarcely be adequate for proper washing and entirely inadequate for power purposes. In most cases it will not be possible to avoid a conflict with prior rights unless the property was located before the accumulation of such rights by others. These rights may consist in preëmptions of water, claim and mill sites on the ground favored for the mill. Towns and the owners of dwellings and agricultural lands have a right to damages if injured by débris or if the domestic water supply is made impotable by mill wastes. The progress of development in the particular mine under consideration located at high altitudes may, by lowering the ground water, cause the water supply to fail entirely. At high altitudes there will be seasons and years when the supply of water is insufficient to carry away the tailings, and their accumulation at the points of little slope during such times will be the forerunner of serious difficulties later on. Other objections to high-altitude sites lie in the liability to snowslides, the shortage of labor and costly means for obtaining supplies and transporting concentrates. The only advantage that the high-altitude site offers is in cheapness of transportation of ore to the mill. Small mills may deem this point of great weight, owing to the initial cost of a transportation system, but it should not be allowed to weigh against the factors that have been mentioned. The cost of a ton of concentrate by wagon road will usually figure out greater than the cost of transportating a ton of original ore to a mill site some distance from the mine—the first cost mentioned, like the second, being based on a ton of original ore.



A DISADVANTAGE OF A FLAT MILL SITE. STACKING TAILINGS IN THE FLAT RIVER, MO., DISTRICT

Unless other factors greatly outweigh, the mill site will be located in the lower part of the mountains and at some point accessible to a railroad by a spur on an easy grade. In such an area it will usually be easy to find steeply sloping sites, gently sloping sites (from 15° to 28°) and flat sites. For concentrating mills the steeply sloping site should ordinarily be rejected. Such sites do very well for stamp mills where the departmental operations are few and the movement of the ore, owing to its fine state of division, can readily be had by gravity flow.

Where steep mill sites are employed for concentrating mills, there is no attempt made, as a rule, to have all the steps connected by gravity flow. The concentrating and crushing machinery is usually assembled under the same roof, preliminary crushing machinery being placed on the hillside with gravity flow from one machine to the other and the hillside forming one end of the inclosure occupied by the plant. The remainder of the mill in this

sort of a plan rises from the flat ground at the foot of the hill, the machinery being placed on various floors supported by a superstructure rising from the flat ground. I believe that there is now no doubt in the minds of thoughtful designers that the preliminary crushing machinery should be housed in a building separate from the concentrating mill proper. The reasons for this have been discussed at length in my treatise[1] on ore dressing, and the problem of the proper slope of the mill site resolves itself into two parts—the degree of slope for the crushing plant and the concentrating mill proper. An axiom of mill designing is to place as much of the machinery and floor weights on the ground as it is possible to do, or in lieu of this, as near the ground as is possible. It is evident that with the steeply sloping mill site it will be possible to rest all the machinery for crushing on the ground and at the same time avoid the use of elevators or conveyor belts by stringing the equipment down the hill. Further, only a light structure will be necessary for covering the equipment. On the other hand, such an arrangement will entail expensive foundations and will require much labor to operate and will be fatiguing to superintend. If, in addition, the mill proper be strung out below the crushing plant, these disadvantages will be accentuated. The terrain then for the crushing plant boils down to a gently sloping or flat site. On either of these a satisfactory crushing plant can be erected, but since the mill proper should rest on a gently sloping terrain, the crushing plant will have to be on ground of like character unless there is a natural bench on the hillside breaking its general slope. The long axis of the crushing plant, corresponding to the foundation line of the crushing machines, will be laid down along the slope of the hill and at right angles to the long axis of the concentrating mill proper, which will be laid down the hill slope. I believe this arrangement is almost ideal for flat or gently sloping sites, but some exigency of the site might render a different arrangement or more or less modification preferable. The design of a crushing plant arranged in the way indicated will require the use of conveyors and elevators, but conveyors are not the bugbears they used to be since they can now be installed so as to require the minimum of attention in operating and if some sort of adequate sampling equipment is to be provided, elevators will have to be installed for all degrees of mill-site slope.

The Advantages of Sloping Sites

The only advantage of the gently sloping site over a flat one for the location of the crushing plant is that very little excavating will have to be done for foundations and openings for conveyors and elevators.

In the case of the mill proper, the principal considerations affecting the degree of the mill-site slope are the necessity for resting the weight, as far as possible, on the ground and the flow of water in the launders. The slope need be no greater than to allow of the economical transportation of material from one department to another by water flowing in launders. It will scarcely be believed that any advocate of the flat site proposes to gain the advantage of having the machinery weights on the ground by moving material from one group of machines to another by mechanical means. What is usually done on the flat site is to erect artificial terraces to support the machinery entirely off the ground to enable the rejects from one department to flow to another by the aid of water in launders. For simple flow sheets where the bulk of the material treated is in a fine state of division, this mode of construction would not be open to any great objection, but the floors so carried off the ground should not be too numerous or to far off the ground, and floors should not be placed over one another.

In some cases the machinery-platform type of construction may be cheaper than the breast walls and other details of construction necessary to a mill built on a gently sloping site and with all the heavy machinery resting on the ground.

The flat site, pure and simple, is one built flour-mill style with a succession of floors built one above the other supporting machinery, all being supported from the same frame resting on the ground. The disadvantages of such an arrangement have been frequently stated, and it will be idle to repeat them in full here. There is a general impression that this type of mill is cheaper than other kinds. If this is admitted, the advocates of it argue that since for the same flow sheets this sort of plan, and any other that may be used for comparison, has the same machinery it will do equally as good work. Will this not be a sufficient answer to that sort of argument? If the same machines arranged to the same end are put into two factories, one dark, unsanitary, crowded and inaccessible and the other with plenty of light and with the machines arranged for the greatest freedom from interruption from repairs, other things being equal, which will return the greatest profit to the owners? But the first cost of a mill with superimposed floors is actually greater than a properly designed mill resting on a gently sloping terrain, for if equal floor space be provided in both types, the flow sheet being the same, the cost of the heavier structure required in the first case will more than offset the greater cost for lighter building material required in the second. Where stereotyped designing used to save over special designing preceded by careful test work was by resorting to closed circuits, to which expedient the superimposed floor plans lend themselves readily, but with the better means for slime treatment we have today, light crushing and return of middlings to the upper end of the mill is no longer necessary or desirable. In most ore-dressing problems it is today possible to keep all the middlings moving ahead or down the mill. If a flat site were ever compulsory with me, I would gain the advantages of a gently sloping site by using suspended floors, and the difference in cost between doing this and building on *terra firma* on the slope would not be much one way or the other and the advantageous arrangement would compensate.

[1] "Theory and Practice of Ore Dressing," by Edward S. Wiard.

Operating Costs at the Liberty Bell Mill

The mill of the Liberty Bell Gold Mining Co., at Telluride, Colo., has a maximum capacity of 175,000 tons annually and during 1915 milled 174,000 tons. The metallurgical process, well-known to operators, is cyaniding with concentration as an auxiliary. The mill has cost, from 1897 to 1913, $345,000. Since 1913 no charge has been made to construction. Of course, part of the cost went into canvas plants which were scrapped, and part represents replacements partly destructive of old work. About 700 hp. is required for the mill operation.

The recovery in the mill is, in stamp bullion, 1% of gold and no silver; in concentrates, 5% of the gold and 9% of the silver. In miscellaneous cyanide products, including bullion, slag, etc., the recovery is 82% of the gold and 67% of the silver, making a total recovery of 88% of the gold and 76% of the silver. About 600 gal. of water per minute is used, almost solely to dispose of tailings. The crusher in use is a T. L. Smith gyratory No. 6. The ratio of concentration is 58:1. The assay of mill heads from 1899 to 1915 inclusive was $7.89; the tailings, $1.44; the percentage of extraction, 82%. In 1915 the total combined extraction was 85%. The mill and shop employ about 47 men, the shop crew doing some mine and tramway work.

Some of the principal materials used in milling and their costs during 1915 are shown in the accompanying table:

MILL COSTS AT THE LIBERTY BELL PLANT (174,100 TONS)

Crushers	$969
Shoes and dies	4,130
Screens	242
Coal for heating	9,069
Cyanide	37,393
Zinc	13,425
Lime	9,015
Acid	1,464
Lead acetate and litharge	4,569
Tube mills	2,068
Pebbles	5,125
Linings	600
Batteries	5,726
Agitators	389
Pumps and compressors	2,231
Filtering	6,715
Zinc boxes	1,124
Buildings and heating plants	5,225
Electric plant	1,802
Concentration	5,672
Concentrate treatment plant	3,566
Settlers	1,181
Pipe lines	3,339
Classifiers and sizes	1,350
Power	37,847
Total	$164,236

TOTAL MILL OPERATING COSTS (174,100 TONS)

Superintendence	$2,534.80
Crushing	5,313.55
Concentrating	9,164.50
Stamping	31,620.62
Regrinding	16,562.55
Settling and agitating	10,071.27
Filtering	9,922.11
Precipitating	17,391.28
Pumping	7,832.35
Cyanide	37,847.86
Lime	9,605.26
Tools	649.49
Sundries	278.17
Assaying and melting	7,758.47
Heating	12,422.87
Lighting	2,435.46
Depreciation (5%)	17,760.89
Maintenance and repairs	36,749.02
Lubricating	1,937.59
Tests	1,086.76
Watchmen	1,477.80
Cleaning	2,399.89
Total	$242,822.56
Per ton	$1.394

Specifications for Purchase of Leather Belting

The following specifications for leather belting, based on requirements of service rather than methods of manufacture, were given in *American Machinist,* Apr. 20, 1916.

Strength—Ultimate tensile strength should be as high as possible without sacrificing other desirable qualities, in order to protect the belt from unusually severe strains to which most belts are occasionally subjected. Tensile strength should be specified in pounds per inch of width.

Stretch—A belt that stretches unduly in service is a source of considerable trouble and expense, yet it must yield instead of breaking when subjected to severe strains. Even when operated far below its capacity, however, leather will permanently elongate in service for some time after installation. Existing specifications allow 8 to 12½% elongation of the test specimen, but actual tests of the best brands show double this amount.

Pliability—The value of the power consumed in friction between the fibers during the life of a belt is probably many times the cost of the belt. Even a small gain in pliability would therefore be quite worth while. Greater pliability also means better pulley contact and less slip. An accurate method of testing for pliability should be worked out and belt makers given every inducement to develop this quality.

Thickness—As a general rule, the thinner the belt the less power required to bend it around the pulleys, the less wrinkling on the inside and the less stretching on the outside. Whatever the thickness, it is of prime importance that it be uniform, especially on light, high-speed machines where vibration is serious. It is obvious that some tolerance must be allowed, and $\frac{1}{32}$ in. is entirely feasible, although this degree of uniformity is seldom attained unless careful inspection is enforced.

Weight—The self-interest of the maker leads to the lightest weight consistent with the required strength. With strength specified in pounds per inch of width, thickness and weight need not be mentioned.

Piping—When a belt passes over a pulley, the inner surface is compressed and forms corrugations. A certain amount of wrinkling is inevitable; but when it becomes very pronounced, the area in contact with the pulley is materially lessened. This condition is known in the trade as "piping."

Cemented Joints—With reasonable care a cemented joint should be as strong as the remainder of the belt and should be so specified.

Injurious Blemishes—Such a thing as a perfect hide is unknown in the trade, but proper selection of the strips from which the belting is made should eliminate most of the injurious blemishes. Such selection should be insisted upon in first-quality belting.

In a symposium in a later issue of the same publication covering this matter, the following additional features were brought out:

Louis W. Arny, president of the National Association of Leather Belting Manufacturers, agrees with the foregoing specifications except in regard to tensile strength, which he considers as inseparable with stretch. He says that the belt would jump the pulley long before the ultimate tensile strength was reached. He says that a specification of weight does not secure for the buyer any better quality, but only more quantity.

C. B. Auel, of the Westinghouse Electric and Manufacturing Co., also states that tensile strength is not a prime specification and that it has been the experience of his company that a stretch of 16 to 25% is excessive in the best brands.

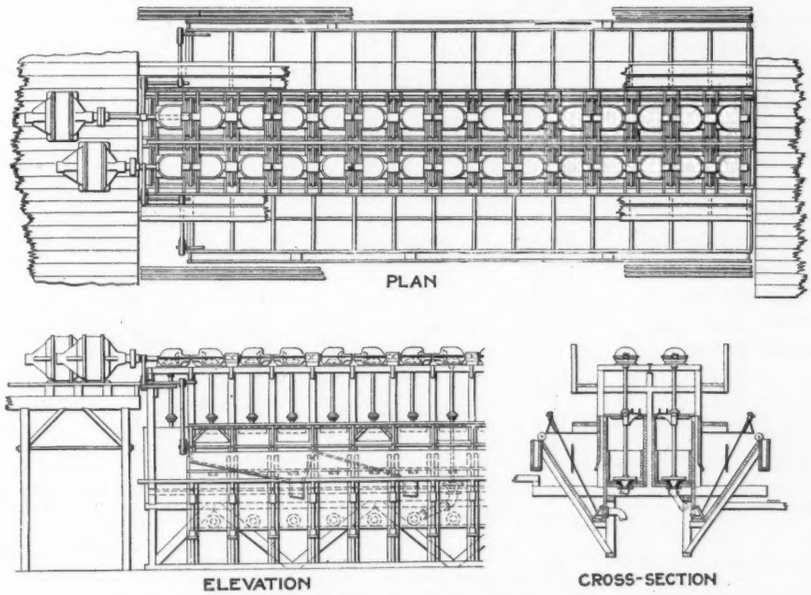
N. G. Near suggests the following good rough-and-ready specification for pliability: "The belt must be so pliable that it will run — — inches slack on — — foot centers and transmit — — horsepower while running at a speed of — — feet per minute. It is well, of course, to give the pulley sizes and speeds and state which is the driving and which the driven pulley. Where the drive is a small one and the belt a narrow one, it would hardly pay to give all details of this kind; but where there are many drives of this type in a given plant, pliability could easily be tested in this way on one representative drive.

Apparatus Used in Flotation

By Herbert A. Megraw

SYNOPSIS—Machines actually in use at flotation plants are limited to three classes. These are typified by the Minerals Separation, Callow and Wood machines. Each is described, together with some of the more prominent modifications.

Since the beginning of operation of the flotation process a large number of machines of different designs have been devised, manufactured and applied to flotation concentration. These have been included in three types. The first is the agitation machine, of the class that is included in the designs used by Everson, most of the preceding inventors, and a great many succeeding ones. This type of machine depends upon violent mechanical agitation to mix oil and air into a pulp. It embraces such well-known machines as the Minerals Separation device, now widely used. A large number of similar machines, having different minor details, have been built to meet the requirements of particular companies working with particular ores. A description of the Minerals Separation apparatus is given herewith. It depends upon ordinary flow for skimming the froth, while many machines that have been made up on similar lines have incorporated in their design some mechanical means for skimming off the froth as it forms. A favorite method of doing this is by means of sheet-metal blade attached to link belt traveling slowly above the surface of the machines and skimming off the froth.



THE MINERALS SEPARATION MACHINE

The Minerals Separation machine as used at Anaconda, and mentioned by Laist and Wiggin in their paper,[1] is shown in the accompanying drawing. The feed is introduced in the first agitator box at the motor end of the machine. From this box it passes to a second box through an opening in the partition—shown in the elevation drawing. From this second agitation compartment the pulp passes into the first spitzkasten, where the first concentrate froth is removed, and the remaining pulp passes through a pipe the inlet to which is controlled by a valve to the third agitating box. From this agitating box the pulp passes to the second spitzkasten and so on down through the machine until it is introduced into the fourteenth spitzkasten. The discharge from the fourteenth, or last, spitzkasten leaves the machine as tailings. The first four to seven spitzkastens make concentrates, and the remaining ones make middlings that are returned to the system. The drawing shows a double machine, each one, however, being run as a separate unit.

The lineshaft is driven by a 150-hp. motor at a speed of 385 r.p.m. The machine under load requires about 100 hp. The vertical shaft carrying the impeller revolves at a speed of 243 r.p.m. These impellers are of the usual Minerals Separation type, having four blades placed at 45° to the vertical. They are 2 ft. in diameter. Each pair of impellers is arranged so that one revolves in one direction and the other in the opposite direction, thus tending to balance the side thrust on the lineshaft. The bevel gears that drive the impeller shaft are cut steel and run in grease. The impeller shaft is supported both vertically and horizontally by ball bearings. In some cases it has been found of advantage to place the motor on the other end of the machine from that shown in the drawing, especially if it is necessary to heat the pulp to over 700° F. There is more or less steam rising from the pulp, especially at the feed end, which condenses on the motors, and by placing the motor at the discharge end this trouble is practically eliminated.

Each machine makes three products: Concentrates, which go to the dewatering division; middlings, returned to the head of the machine; and tailings, going to waste. Concentrates are taken from the first 3 to 5 spitzkastens and middlings from the last 9 to 11. Some of the pulp is overflowed from the last three spitzkastens together with the froth. About 6 to 8 lb. of 60° sulphuric acid per ton of flotation feed is used, together with 2 or 3 lb. of kerosene sludge acid and ½ to 1 lb. of crude wood creosote. A portion of the wood creosote is added ahead of the Hardinge mill—about 0.03 to 0.05 lb. per ton of feed—and the remainder is added in the six agitator compartments. The sulphuric acid and sludge acid are added at the head of the machine. The pulp is heated at from 60° to 70° F. by passing live steam into it at the head of the machine. Three machines are used for treating sand and the fourth for treating current slimes from the upper portion of the mill. Each has a capacity of about 400 tons per day on sand and 175 tons per day on slimes.

The second machine in popularity is the Callow, using a system that dispenses with mechanical agitation for

[1] "Bulletin," A. I. M. E., March, 1916.

air incorporation into the pulp. In the Callow apparatus the air for bubble formation—serving also for agitation—is compressed air forced through the bottom of the flotation cell. The air passes through a false bottom that may consist of canvas, silica brick or some other similar material, but usually canvas is used. Passing compressed air under low pressure through the canvas subdivides the air into small bubbles, thus supplying the necessary agitation and also the froth-forming constituents. The Callow unit consists of a tank with a bottom inclined at from 3 to 4 in. to the foot. It is 20 in. deep at the shallow end and 45 in. deep at the other end and may be built either of steel or of wood, the latter being considered preferable. The bottom of the tank consists of a porous medium made of about four thicknesses of loosely woven canvas twill, properly supported by a backing of perforated metal to prevent its exploding when under air pressure. Through the porous medium compressed air is forced by a blower. The space underneath this porous bottom is divided into eight compartments, each connected by an individual pipe and valve with the main air pipe. By this means the air pressure to each compartment may be regulated to correspond to the varying hydraulic heads in the tank. A pressure of from 4 to 5 lb. per sq.in. is commonly used, each square foot of porous medium requiring from 8 to 10 cu.ft. of free air per minute.

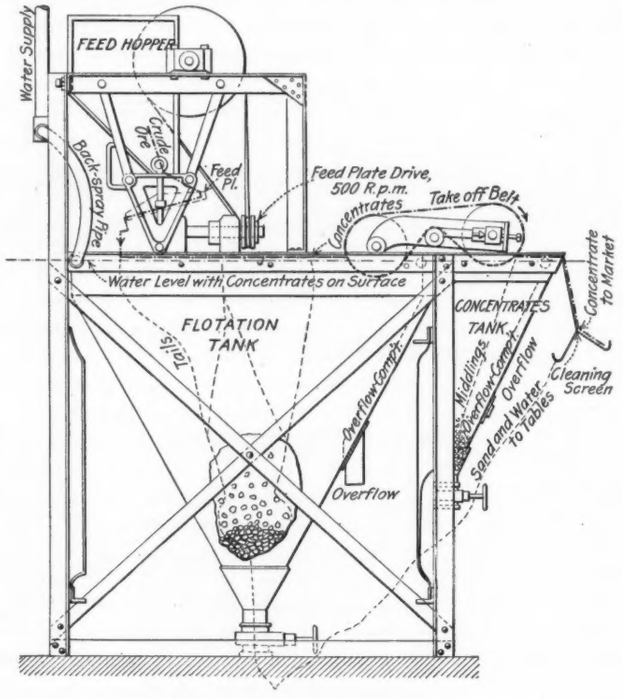
The longitudinal edge of the tank is provided with an overflow gutter for the reception and discharge of froth. The lower end of the tank has a spigot discharge fitted with a plug valve to maintain a uniform water level within the tank and thus, in turn, maintain a constant discharge of froth under all varying conditions of feed supply incident to practical milling operations. The water level may be varied, but is usually maintained at about 10 to 12 in. below the level of the overflow lift. The tailings are discharged through the spigot, and concentrated froth is conveyed to the cleaner separating cell. The cleaner is simply an additional unit intended to treat again the low-grade concentrate obtained from the initial, or roughing, device that performs the first operation. The Callow apparatus does not employ any violent mixing means, but preliminary mixture in a Pachuca tank is usually relied upon. Recent experiments, however, at operating plants have shown that this tank may be dispensed with without in any way interfering with the good results obtained.

Macquisten Surface-Tension Machine

The third type of flotation machine depends entirely upon the surface tension of water in contact with air and places no dependence upon oil or agitation by mechanical means or air bubbles. This type does not make a froth, but simply floats the sulphide upon the surface of still or gently flowing water. The earliest commercial machine of this type is the Macquisten tube, which has already been described at length in the *Journal*.[2]

The Macquisten tubes are made of cast iron. As ordinarily used they are about 6 ft. long, 1 ft. in diameter inside and weigh about 450 lb. They have two tires, much like the tire-type tube mill, which rest upon rollers. The discharge end of the tube is entirely open, while the feed end is closed except for a hole in the center large enough to admit the pipe that feeds the pulp. Inside the tube is a helical groove, intended to move the pulp granules forward in the tube. The pitch of the interior helix may be anything from 1 to 3 in., depending upon the ore under consideration. The discharge end of the tube fits into a separating box, the joints between the two being water-tight, while the tube is freely revolved. Means are provided for overflowing from the box a thin layer of water that contains the floating sulphides. The whole operation of this machine, which is well known at this time, is simply feeding the pulp at the head end of the machine, the sulphides having a large number of opportunities to float on the surface of the water, since they are raised to the surface by the revolution of the tube and their opportunities for floating are limited only by the mineral grains being forced out of the discharge end of the tube by the helix of the interior. The Macquisten tube has been successfully used in several cases, although its application at the present time is not wide. It is now in use at the Morning mill of the Federal Mining and Smelting Co., at Mullan, Idaho, and at the Iron Mountain mill of the same company, in Montana.

The Wood flotation machine utilizes the same principle that is employed in the Macquisten, but in a somewhat



THE WOOD FLOTATION MACHINE

different way. It consists of a rectangular structural-steel frame about 5½ ft. high at the back, 5 ft. wide and 5 ft. long. Supported in and on this frame are a series of feed hoppers and tanks, feed mechanism, etc. At the back is supported a rectangular feed hopper, the front, ends and part of the back of which are vertical. About two-thirds of the back slopes to the front at an angle of 45°. The bottom of the feed hopper is about 4 in. wide and about 4 ft. long and is made of a removable steel sheet which is used as one of the feed-opening adjustments. On the front of the hopper is a vertical movable gate which, in combination with the bottom, gives a wider range of adjustment of the feed openings. Inside the hopper is a longitudinal shaft studded with short pins, and this is

[2] "Concentration Upside Down," Eng. and Min. Journ., Oct. 26, 1907.

revolved at the rate of 90 to 100 r.p.m. and serves to keep the ore in the hopper loose and free from channels. Suspended from the upper frame is a triangular truss with cast-iron ends. This truss carries the feed bar, which is made of angle-iron and wood, carrying a number of 3½x ¼-in. screws which project into the feed openings of the hopper. Below the feed bar in the trough is supported an adjustable feed pan 8 in. wide and 4 ft. long, which receives ore from the feed hopper as it is delivered to the feed bar. The truss carrying the feed bar and feed pan is vibrated on a horizontal plane by means of a small eccentric attached to the main frame of the machine and connects with the truss by means of a flexible hickory drive rod. The eccentric shaft is driven about 500 r.p.m.

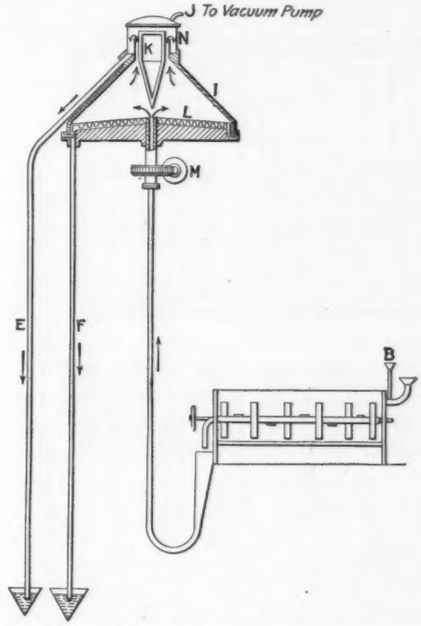
The ore dropping at the back of the feed plate is spread out into a thin, even sheet by the time it has traveled 8 in. at right angles to the vibrations, and is then dropped on the surface of the water contained in the main tank. This tank has a valve at the point, or bottom, above which is a diaphragm to steady the flow of tailings that collect in the tank. At the front of the tank is a partition that has its top edge ¾ in. below the top of the tank. This edge is an overflow weir and maintains a constant level of water in the tank. At the back of the tank there is a spray pipe from which water discharges in a large number of fine jets parallel to and just below the surface of the water contained in the tank, thereby creating a smooth surface current toward the front of the tank. Halfway between the back spray pipe and the front of the tank is a second spray pipe with a smaller number of holes, which assists the back pipe to maintain the surface current uniform clear across the tank. In front of and bolted to the main tank is a narrow rectangular cone that has a bottom discharge and overflow weir similar to that of the main tank. The joint between the tanks is made water-tight by means of a light iron channel set over the top of the tank.

Supported on the top of the main frame directly over the joint of the tank is a take-off, or concentrate-collecting device, consisting of two 6-in. by 5-ft. rollers and one 2½-in. by 5-ft. roller, supported at the ends by adjustable arms. Around these three rollers is passed a heavy fabric belt which picks up the concentrates from the surface of the water in the main tank and carries them over to the concentrates tank where they are washed off under the surface of the water in that tank and passed on over the weir to a settling or filtering device.

The power required for the operation of the machine is about ¼ hp., and the water required varies from 5 to 10 gal. per min. A partly submerged corrugated rubber cylinder may be submitted for the moving plane of water.

Elmore Vacuum Separators

Among the older apparatus used in flotation is the Elmore vacuum machine. This depends, apart from the usual dependence upon oil in froth flotation, upon the fact that air or gas dissolved in water is liberated partly or entirely by subjecting it to a pressure less than that of the surrounding atmosphere. Liberated gases of this kind may be augmented by the generation of gases in the froth or by the introduction of some external force. The gases attach themselves to the mineral particles and, being largely increased in volume as a result of the partial vacuum applied, cause the mineral particles with their attendant bubbles of air or gas to float to the surface of the liquid. A complete description of this process has already been given in the *Journal*[3] by Alexander Stanley Elmore. The apparatus for carrying out this idea is shown in the accompanying drawing. The preliminary mixture of air, froth and oil is made in the beater, the mixture then going into the pipe which carries it up to the separating machine. In this machine a partial vacuum is maintained, while the weight of the tailings in the tailings pipe supplies the power for elevating the feed into the machine. Vacuum is applied in the machine, the concentrates rising with the froth formed and being discharged through the cencentrates pipe. The tailings settling upon the conical floor of the machine are continuously raked off by the revolving arms, falling into the concentrates-discharge tube. The process has been used successfully in con-



ELMORE VACUUM FLOTATION APPARATUS

centrating some of the Scandanavian iron ores, but at the present time is not known to be in use in this country.

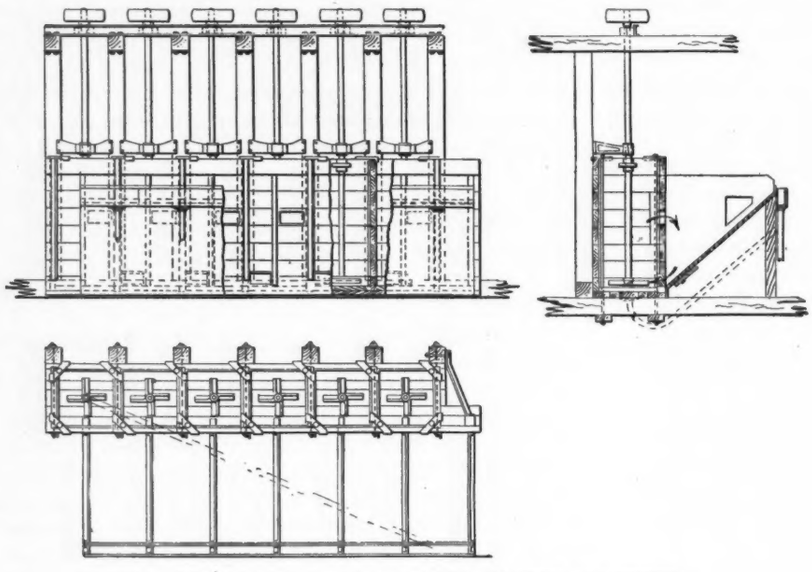
One of the principal devices used in flotation now is the Hebbard machine, but this is well known as the Minerals Separation machine. The Hebbard is essentially similar to the Hoover, the original Minerals Separation apparatus, but there are some differences in details. The Harvey modification of the Minerals Separation, or Hebbard, machine is driven from the bottom.

U. S. Patent No. 1,064,209, June 10, 1913, granted to James Hebbard, of Broken Hill, N. S. W., Australia, sets forth an improvement upon his original machines. In the earlier arrangement the apexes of the spitzkasten were carried down to a considerably lower level than the bottom of the mixing vessels, but in this invention the mixing vessels and the spitzkasten are on the same level; that is, the bottoms of the spitzkastens are substantially level with the bottoms of the mixing vessels.

This form of apparatus embodies a number of mixing vessels substantially on the same level and side by side, and a number of spitzkastens, also on the same level and adjoining the mixing vessels, but staggered in relation to their plan view; that is, the first spitzkasten contacts with

[3]Eng. and Min. Journ., May 11, 1907.

half of the first mixing vessel and with half of the second, the second spitzkasten contacts with half of the second vessel and half of the third, and so on. At a convenient point in the height of the first mixing vessel is an outlet leading into the first spitzkasten. At the bottom of the other half of the first spitzkasten is an orifice leading into the bottom of the second mixing vessel and so on. Each spitzkasten is thus provided with two openings, one at the high level by which the agitated pulp is passed from an agitating box to it, and the other at a lower level by which the pulp that sinks passes to the next agitating box in the series. The spitzkastens are supplied also with concentrate launders. Each of the collecting launders is provided with a pipe for removing the froth, and if any of this material needs to be re-treated, it can be sent through this pipe back to a preceding agitating compartment. In the accompanying drawing, which shows the layout and operation of the machine, the pipe is shown leading from the concentrate trough of the last spitzkasten back to the first agitating compartment.



THE IMPROVED HEBBARD FLOTATION MACHINE

The Murex Magnetic System

Mention should be made of the Murex process, which, although not an oil-flotation process at all, does depend upon most of the principles of flotation. In this case the magnetic paint is mixed with oil and then put into the pulp, where it preferentially clings to the sulphide particles that are to be removed. The magnetically painted particles are removed from the mass by a magnetic-concentration machine. The method of applying the magnetic paint is interesting, since it is practically a mixing process such as may be used in flotation. The process is carried out in a small tube mill, in which grinding pebbles are replaced by small metal balls, not heavy enough to provide grinding efficiency. The magnetic paint adheres to these balls, and by them is carried to the mineral particles, the balls in addition providing a gentle agitation by means of which every particle of sulphide comes in contact with sufficient magnetic oil paint. Machinery used in the process is that used in general milling except for the magnetic separators.

Developments at Vindicator

The new concentrating mill of the Vindicator Consolidated Gold Mining Co., Cripple Creek, Colo., was completed in 1914, but it was not until the early part of 1915 that it received its full tonnage. Operations over 15 months have shown that it has fulfilled its purpose, and in fact in nearly every department better results have been obtained than were indicated from experimental work. During the year the mill handled a daily average of 250 tons per 8-hr. shift. An average ratio of concentration of 11 to 1 was maintained. The recovery in handling ores from an average value of $2 per ton was about 55%. Profits from milling operations have been nearly double what was indicated from the experimental work, largely due to the fact that milling costs were cut down to about 20c. per ton. A complete return of the capital expended was shown after 12 months' operations.

About 2,000,000 tons of low-grade ore that is on the dumps of the property averaged $2 a ton or somewhat better, and this, in addition to a large block of low-grade ore in the mine and filled stopes which cannot be worked at a profit with present metallurgical systems, can be expected to yield a handsome profit if a process can be devised whereby milling grades of ore can be treated on the ground with a high percentage of extraction at a low cost of operation.

Metallurgical engineers have been experimenting on this problem for a long time and have tried various methods, including flotation and cyaniding, both in laboratory tests and in actual practice. They are now using a flotation unit of 10 tons' daily capacity. As a result of these experiments, it has been recomended that the old concentrator at the Golden Cycle shaft, which is now obsolete, be remodeled into a flotation unit of 300 tons' daily capacity, sufficient to treat all the reject material from the Golden Cycle orehouse, as well as to experiment on all grades of ores from both shafts. An extraction of 90% or over is expected, at a cost of less than $1 per ton. This plan will enable the operators to determine the best and most economical process to use on the ore, and when this is determined, plans for a larger and thoroughly modern flotation mill of not less than 1,000 tons' daily capacity will be considered. Such a mill would probably cost not over $200,000, while a cyanide mill of the same capacity would cost more than $750,000.

Cost of Electric Power

The following costs of electric power for mining and milling purposes are given by the St. Joseph Lead Co. in its report for the year 1915:

Plant	Kw.-Hr.	Cost	Cost per Kw.-Hr.
Bonne Terre	9,935,513	$84,020.60	$0.0084
Leadwood (a.c.)	17,560,000	96,989.67	.0055
Leadwood (d.c.)	2,822,626	21,776.65	.0077
River mines	4,041,919	63,324.64	.0156
Totals	34,359,458	$266,111.56	$0.0077

A Map of Alaska, 10x15 in., no contours, scale 1: 12,000,000, has been published by the United States Geological Survey and is for sale at the price of 1c. per copy or five for 3c.

The Use of Belt Conveyors*

SYNOPSIS—Conveyor belts have not been given the technical study they deserve, and they have not given the returns that might have been obtained with more care. The use of balata, cotton and rubber belts is discussed in relation to the kind of material that has to be transported.

All endless conveyor bands may be said to have grown from small hand-operated horizontal types to the present-day conveyors capable of carrying large quantities of material great distances and heights and requiring considerable power for driving purposes. Much skilled attention has been given to the proper design and construction of items which comprise the accessories required for good belt transmission, and also to the construction and manufacture of the belts themselves; as a consequence, many of the faults attached to the running and maintenance of conveyor belts have been overcome. The considerable variations encountered in striving to obtain reliable figures on which to base one's calculations have prompted the authors to compile data on conveyor belts and to add some experience with regard to the design, maintenance and testing of belts, in the hope that the matter submitted may be of interest to the engineer and of some use to those concerned with the design or the running of belts.

Testing Conveyor Belts

In comparing conveyor belts and adjudicating on their relative commercial values, four points have to be taken into consideration: The build or construction of the belt, its suitability for the work intended, and manufacturing defects; the strength and weight of the cotton duck; the adhesiveness between adjoining plies; and the quality of the rubber. To the engineer must be allotted the duty of determining the first and most important of these qualifications. To the testing and chemical engineer falls the task of ascertaining the strength of the cotton duck, the suitability of the rubber and the quality of the frictioning.

It seems almost unnecessary to place on record the advisability of utilizing the testing engineer, but present-day methods on the Rand so willfully neglect him that little apology is required for pointing out that when it is possible to obtain a fairly accurate forecast of the quality of a belt, surely such should be obtained. The main object of the consumer must be to raise the quality to a maximum, while decreasing the price to the minimum. It is unfortunately the case that the best salesman or the lowest tender often obtains the order. When an agent, acting on behalf of the buyer, executes the order, he rarely includes a quality clause, or if he does, he places this second to the price consideration and has not the means, nor usually the inclination, to determine whether the quality is that demanded.

The effect of such a system of purchase leads to a lowering of quality; to the ousting from this market of reputable makers and merchants; to unfair allocation of blame when an early failure of an untested belt is to be recorded; and to unfair excessive charges on other purchasers when an agent or maker is called upon by the manager or engineer of a mine to replace or make an allowance for a belt that has failed sooner than either had expected, even though this belt failed not from inferior quality, but from unsuitable local conditions or careless handling.

Balata belts are tested by determining the strength of the warp and filler of the canvas and by ascertaining the frictioning or adhesion between adjoining plies or layers. In belting the main strength must lie in the warp, though that of the filler should be but little inferior. This strength is found by breaking in the tension machine a section of the belt one inch in width. Care must be taken in cutting this that no thread in the line of the pull be broken before the test.

Strength of Cotton Duck

When for some reason only one ply can be obtained for this test, it is advisable to cut a section just over an inch and detach therefrom single strands until the exact inch is reached. The grips also must bear evenly over a surface, so as to avoid pinching the belt in one place; this may be partly avoided by making the gripped portion larger than an inch—say, one and a half inches, with a taper to one inch. The tested portion should be, over the inch section, at least 3 in. in length.

A specification for the cotton duck used in this belting should note the weight of duck used (oz. per lin.yd.), the number of yards per inch, both for warp and for filler, the tensile strength of the warp and of the filler, the amount of stretch in the belt, and the number of plies in it. To illustrate the variations that exist in this class of belting, the samples being submitted for one particular duty, I may quote the following results:

SAMPLES TESTED LENGTHWAYS OF BELT (WARP)

Tensile Strength of Total Belt 1 In. in Width

2,806 lb.	No. of ply 8
3,180 lb.	No. of ply 6
3,168 lb.	No. of ply 8
3,564 lb.	No. of ply 6
3,600 lb.	No. of ply 4
3,916 lb.	No. of ply 8
3,136 lb.	No. of ply 8
1,320 lb.	No. of ply 6

If we neglect the last one as being an inferior lot, we still find a variation amounting to over half a ton per inch in the breaking strain of the different duck used. This means an additional load capacity of 15 tons on a 30-in. belt. The tensile strength of the filler in certain belts examined shows even greater differences:

STRENGTH OF BELT FILLER

Samples Tested, 1 In. in Width

0.990 lb.	No. of ply 6
1,440 lb.	No. of ply 8
2,288 lb.	No. of ply 10
1,980 lb.	No. of ply 8
1,584 lb.	No. of ply 8
1,584 lb.	No. of ply 8
1,232 lb.	No. of ply 8

The difference of a breaking strain of 750 lb. per 1-in. section in the filler of two 8-ply belts is surely worthy of consideration when placing an order. It is to be noted that the strength of the warp is greater than that of the filler, and agents should note in submitting samples for test that these be at least 10 to 12 in. in length and about 3 to 4 in. in width, except when the strength

*Excerpt from article by A. Robertson and A. McA. Johnston, in the "Journal" of the South African Institution of Engineers, March, 1916.

of both warp and filler is required, in which case the section submitted should be 10 in. square.

The adhesion between adjacent plies of duck is determined by maintaining a steady pull in separating them. A section of the belt 1 in. in width is taken, and one, or even two or three, of the plies are separated by hand for a length of 2 in., and the two ends caught in the clamps of the machine shown in Fig. 1. A steady pull is applied by turning the wheel, the rate of turning being regulated so that the jaws may move apart 2 in. per min. The spring balance registers the resistance set up and indicates the effectiveness of the balata frictioning. The adhesiveness depends on the quality and quantity of the balata used and the success of the operation known as frictioning.

The Pennsylvania Railroad Co. requires that the frictioning of its air-brake hose be such as to support a pull of 25 lb. while separating at appromixately the rate given. Much air hose on our market scarcely maintains a 1-lb. pull when separating contiguous plies.

A specification for balata belts might well demand a friction test of at least 20 lb. This figure is not often reached here, but if demanded, it could easily be reached and would form some guarantee that the belt plies would not readily part.

The following results from a series of tests show actual figures on samples of balata belt at present in this market:

FRICTION TEST ON BALATA BELTING

Lb.	Lb.	Lb.	Lb.
24½	18½	15	12
21½	17	14	11
21	16½	13	5

The stretch in the belt is not often determined in the testing laboratory though, given suitable apparatus, this could be easily done. It is always advisable to test the belt as a whole and not over an inch section.

Rubber Conveyor Belts

Similar tests are made on rubber conveyor belts, with, of course, the additional testing and analysis of the rubber. Owing to the greater cost of rubber belting, firms are not keen on supplying test lengths of 9 to 12 in., and as a rule tests of the cotton duck are made on the transverse section. One sample of a very good belt submitted gave the same tensile strength longitudinally as transversely, but this result would not always be found.

In the following table are the records of the total strength of the cotton duck of seven belts recently examined here:

STRENGTH OF COTTON DUCK

	Tensile Strength on 1-In. Transverse Section (6-Ply), Lb.		Tensile Strength on 1-In. Transverse Section (6-Ply), Lb.
A	902	E	1,056
B	858	F	990
C	924	G	1,350
D	825		

The friction tests on these same seven samples showed that none of them was exceptionally good, while one was exceedingly bad and three poor. The tests were made on a 1-in. transverse section.

FRICTION TESTS ON BELTS

	Friction Test Between Cotton-Duck Layers, Lb.		Friction Test Between Cotton-Duck Layers, Lb.
H	10	L	8½
I	14½	M	9½
J	1½	N	6
K	15		

As these results were obtained from belts that are considered the best on our market, it would seem that neither the cotton duck used nor the frictioning is as strong in rubber conveyor belts as in balata belts.

LIFE OF BALATA BELTS

Type of Belt	Put into Use	Taken Off	Actual Life	Tonnage per Week of 6 Days of 9 Hr.	Total Tonnage Carried	Selling Price per Ft.	Cost to Mine per Ton	Cost to Mine per Ft. per Month
30-in., 5-ply, 291 ft., with 7 rows of copper stitching. Conveying crushed fines from crusher to main belt. Note. Ply was increased to 6.	May 1, 1911	Mar. 3, 1913	672 days	5,000	397,546	10s. 2d.	0.089d.	5.42d.
30-in., 5-ply, 402 ft., with 7 rows of copper stitching. Horizontal to fines main belt.	May 1, 1911	Sept. 1, 1912	489 days	8,000	416,779	10s. 2d.	0.12d.	9d.
30-in., 5-ply. 270 ft., with 7 rows of copper stitching. Grizzly fines.	May 1, 1911	Dec. 8, 1912	502 days	7,200	602,733	10s. 2d.	0.054d.	7.18d.
32 in., 5-ply, 180 ft., with 8 rows of copper stitching. Shuttle belt. Note. Ply was increased to 7.	May 1, 1911	Nov. 21, 1912	572 days	12,000	799,429	11s.	0.030d.	8.098d.
30 in., 6-ply, 402 ft. Horizontal fines, carrying crushed rock, delivering on to main incline belt	....	....	414 days	....	529,000	14s. 3d.	0.13d.	....
20 in., 6-ply, 250 ft., stepped to 4 ply. Conveying uncrushed rock from bins to sorting table. Note. This belt had not worn through, but became too thin to support weight of rock at edges.	Jan. 6, 1913	Oct. 14, 1913	....	14,000 (average	126,000	10s.	0.24d.	....
24-in., 5-ply, 305 ft	Dec. 7, 1913	....	....	....	....	....	....	....
32-in., 6-ply, 145 ft	Apr. 15, 1914	....	....	....	....	....	....	....
24-in., 6-ply, 166 ft., stepped to 4-ply, with 7 rows of copper stitching	June 15, 1912	Sept. 8, 1913	....	1,200	450,000	11s.	0.048d.	8.8d.
Material carried, crushed rock 30-in., 8-ply, 300 ft. Sorting belt. Uncrushed rock. Severe drive, running in water continuously.	Feb. 20, 1914	....	....	893 per 10 hr.	320,000	18d.	Cost per 100 tons, 1-8¼	....
30-in., 6-ply, 690 ft. Mill incline.	July 1, 1913	....	....	....	Tonnage to May 31, 1914 —367,820	14s. 4d.	0.322d.	7.16d.
32-in., 5-ply, 492 ft. Main incline, conveying crushed rock to mill and delivering on to shuttle belt.	....	....	394 days	....	467,846	11s.	0.12d.	....

The value of the rubber layer depends entirely on the quality of the rubber used, on the vulcanizing it has received and on its age. One has to handle rubber constantly to realize the depreciation that takes place in this climate, and more especially with the quality of the rubber used for this class of work. It is in my opinion essential in buying a belt to stipulate that it has been but recently imported. Not only does the rubber deteriorate, but the frictioning material used to cement it to the duck loses its adhesive properties.

Two belts that were tested here showed that the rubber layer in each case lost its elasticity to a not inconsiderable extent after a lapse of six months. The thickness of layer was $\frac{3}{16}$ in.; elongation of a section 1 in. wide and measuring 3 in. between the grips, before breaking:

	In.		In.
Sept. 14, 1914	13	Mar. 18, 1915	6
Sept. 14, 1914	8	Mar. 18, 1915	5½

The rubber layer in one sample refused to be detached from the canvas layer. As soon as a grip could be obtained and a moderate pull exerted, the rubber tore, showing both the poorness of the quality and the effect of climatic conditions.

The following results were obtained from seven samples of rubber conveyor belts:

EXAMINATION OF RUBBER BELTS

Incombustible Matter in Rubber, %	Stretch of 3 In. In.	Friction Test Between Rubber Layer and Canvas Layer, Lb.	Incombustible Matter in Rubber, %	Stretch of 3 In., In.	Friction Test Between Rubber Layer and Canvas Layer, Lb.
48.30	13	12	37.07	9½	14
46.05	4½	3	44.04	8	9
42.00	10	9½	59.34	..	..
63.40	5½	6½	39.00	8½	15

The elasticity, or stretch, in the rubber layer is obtained by gripping a section 1 in. wide in the machine used for the friction test, with a distance of 3 in. between the grips. The total elongation before breaking or tearing is thus obtained, as is also the tensile strength of the rubber. The following may be quoted as characteristic tensile strengths of a 1-in. section of the rubber layer of belts in good or fairly good condition and ready for the market here:

TENSILE STRENGTH OF RUBBER BELTS

Stretch of Rubber (3 In. Between Grips), In.	Tensile Strength, Lb.	Stretch of Rubber (3 In. Between Grips), In.	Tensile Strength, Lb.
10	83	8	105
7	67	9½	60
12	120	8½	310
5½	42		

It would be recommended, therefore, that a specification should demand that the incombustible matter in the rubber layer be under 50% by weight; that a section of the rubber layer 1 in. in diameter shall stretch to at least three times its own length before breaking (3 in. to 9 in.); and that the frictioning between any two contiguous layers, rubber and canvas or canvas and canvas, be at least 15 lb. It is probable that these demands could in time be made more stringent.

The Kind of Material Handled

The material handled on our gold mines is quartz. In the breaking and crushing of ore necessary for reduction operations, the quartz in fracturing acquires very sharp edges, which have a most destructive effect on conveyor belts. The abrasive action of these fine particles is great. It was shown in a recent paper on "The Pumping of Mine Water," by Messrs. Izod and Rouillard,[1] that the very fine grits in suspension in mine water, when caught on a filter paper and examined under a microscope, were found to possess sharp corners which proved most destructive to pump liners and piping. This being so, the action of much coarser material may be understood.

[1]"Journal" of the South African Institution of Engineers, Vol. 13, No. 6.

It is owing to the nature of this material that a tripper for delivering from conveyor belts is not a desirable method where such a material as quartz is handled. Owing to the large quantities of water now being used in underground operations, the conditions cited have been accentuated. At some mines the ore is delivered to the head-gear bins in a mushy condition, and where there are no washing trommels adjacent to the bins, the transmission of such material is made difficult, owing to the inconvenience of handling and to the spillage that takes place. Much greater care is then required in loading and in the protection of the belt and its accessories.

Owing to the slight abrasive action of coal, its handling by conveyor belts can be carried out much more efficiently and economically than is the case with quartz or other coarse material. Tripper carriages can be used for most purposes, and the design of the necessary chutes does not present the same difficulties and permits of modifications that are impossible in gold-mining practice.

Other materials are dealt with in a general way in the tables attached to this paper, which give the capacities of belts at different speeds for material of a given weight per cubic foot.

There are two kinds of belts in general use for the conveyance of material—balata belts and rubber belts—and each type has strong advocates in favor of its adoption. We have endeavored to treat the subject as impartially as possible. Both types may be obtained in many qualities and to suit various requirements. Generally speaking, the rubber belts cost from 15% upward more than balata. The high cost and scarcity of rubber at the present time, due to the exigencies of war, must be taken into account in any comparisons of costs between rubber and balata. The detailed construction of any class of belt is the sole property of the makers, but the general essentials should be stated in specifications.

The choice of which type is to be used should have careful consideration, so that the best results may be obtained. For instance, for the transmission of sand even some of the agents for balata belts do not advocate their use, although some of our mines are equipped with no other type; in the same way, some other mines have only rubber belts.

It might be considered advisable on starting a new plant that a comparatively cheap type of belt should be installed in order to lessen the cost of any damage that

PARTICULARS OF RUBBER BELTS

Type of Belt	Put into Use	Taken Off	Life, Months	Tonnage per Hr.	Total Tonnage Carried	Selling Price per Ft.	Cost to Mine per Ton	Cost to Mine per Month per Ft.
36-in. belt, 173 ft. long, 5-7-ply, ¼-in. rubber. Carrying rock to crusher station.	Aug., 1904	May, 1909	57	30	758,777	32s.	.....	6½d.
36-in. belt, 147 ft. long, 5-7-ply, ¼-in. rubber. Carrying rock at crusher station.	Aug., 1904	Sept., 1907	.....	76	828,162	32s.	.....	10½d.
36-in. belt, 173 ft. long, 5-7-ply, ¼-in. rubber. Carrying rock at crusher station.	Aug., 1904	April, 1908	44	....	522,854	32s.	.....	8½d.
24-in. belt, 182 ft. long, 6-4-ply. Carrying sand.	.....	.....	69	68.6	1,586,764	15s. 6d.	.....	2½d.
20-in. belt, 598 ft. long. Carrying sand.	.....	.....	36	66.5	545,400	16s.	.....	5½d.
20-in. belt, 930 ft. long, 6-4-ply. Carrying sand.	Jan. 22, 1905	Sept. 1, 1908	..	80	782,000	10s. 2d.	.....	4d.
24-in. belt, 404 ft. long, 5-ply. Fines to mill.	.....	.....	16	....	205,345	13s. 6d.	.....	10d.
24-in. belt, 864 ft. long, 5-ply. Fines to mill.	.....	.....	11½	....	293,873	13s. 6d.	.....	1s. 2d.
36-in. belt, 147 ft. long, 5-7-ply, ¼-in. rubber. Carrying rock at crusher station.	Aug., 1904	Sept., 1907	36	76	828,162	32s.	.....	10½d.
30-in. belt, 923 ft. long, 7-ply, ¼-in. rubber. Fines to mill.	Jan., 1911	June, 1912	18	117	854,000	24s 4d.	.....	1s 4½d.
40-in. belt, 115 ft. long, 7-ply, 1/16-in. rubber. Sorting belt.	.....	.....	31	.....	390,000	.....	1/10d.	.....

might occur during the time that trials are run, adjustments made and the plant tuned up generally. Where great care is exercised in the design and manipulation of the loading and unloading devices, such a policy would be unnecessary, but we have always the element of native labor to consider and the bustle attendant on all new works.

Balata belts are constructed of various plies of canvas to suit the width and strength of belt required, with pure balata gum well impregnated between the several layers. These belts may be obtained with ordinary or with copper-wire stitching on the wearing edges, and with ordinary or the stepped ply, as is the case with most belts now on the market. Some who have occasion to use balata belts consider that they are more susceptible than rubber belts to changes of temperature, moisture in the air or on materials carried; to contacts with grit or acid; and that they are more difficult to keep clean and are more given to snaking or swinging, to stretching or creeping. We hold that with a well-made balata belt such disadvantages do not become apparent. In all cases the quality of any belt is the decisive factor.

Rubber belts are constructed of various plies of canvas duck to suit the width and carrying capacity of the belt, with the frictioning medium well impregnated between the plies and a covering of rubber on the upper and under sides and edges. These belts are made with plain or with stepped plies. The best classes of belts are constructed with duck weighing 32 oz. per sq.yd., but less costly qualities may be obtained, which have 26-, 28- or 30-oz. duck as the medium. The frictioning medium in all belts is a matter for close attention; loosely woven canvas and balata are said to show up best when new, but to depreciate in use more than the closely woven and rubber-covered belts. When stretching occurs, the strenth of the frictioning decreases. The ordinary specification for rubber belts was to call for 6- or 7-ply with $\frac{1}{8}$-in. rubber face and $\frac{1}{32}$-in. rubber cover on back.

As rubber belts are of high initial cost, it might be well to call for $\frac{3}{16}$-in. rubber face and $\frac{1}{16}$-in. rubber on the pulley side, as with the lesser thickness it has been found that the abrasive action of the material carried caused the rubber covering to be worn out, while at the same time the canvas and frictioning were in good order. A good covering of rubber on the edges of the belt is essential. This point is put forward so that a consistent class of belts may be obtained, with the rubber surface frictioning and canvas as near the correct proportions as possible.

Belts may be obtained with any degree of vulcanization desired to suit the material to be carried. While the makers of belts contend that hard vulcanization gives the best results if large-diameter pulleys are in use, most users like a rubber belt to be easily stretched and elastic. In the running and maintenance of belts where they may have been inadvertently cut or torn, it is possible to repair with rubber and revulcanize if a small vulcanizing set is at hand, as is the case at some mines today.

The systematic painting of belts with P. & B. paint is regarded at some mines as an excellent means of preserving the surface and helping most materially in achieving a good condition of belt and prolonged life. All belts should be housed in, or at least have some form of covering as a protection from the weather, particularly in warm climates.

The Life of Conveyor Belts

Tables giving the services obtained from various conveying installations on our gold mines are given, but some particulars of special conveyor belts may be of interest.

Particulars of rubber belt conveying coal at a Transvaal colliery:

Started up, October, 1904.
Taken off, February, 1909.
Actual running time, 4 years and 4 months.
Condition when taken off, not bad; was made into shorter lengths and used up.
Belt 30 in. wide, 9-8 ply, $\frac{3}{16}$-in. rubber cover, length between centers 520 ft. approximately.
Speed, 460 ft. per min.
Height elevated, 155 ft.
Troughing idlers, 4-ft. centers.
Return idlers, 10-ft. centers.
No guide idlers used.
Total quantity elevated, 2,000,000 tons approximately.
Approximate cost, 0.45d. per ton carried; this cost including new pieces of belt, grease, repairs, labor and, in fact, everything connected with the running and maintenance of belt during the entire period of working.

Slipping was made known by an automatic electrical signaling arrangement connected to the first return idler pulley. A non-runback ratchet-and-pawl arrangement was provided, but never found necessary because there was no tendency to run back, the whole plant being belt-driven and this drive being driven from the main lineshafts. The maximum output of belt was 3,000 tons in 10 hr.

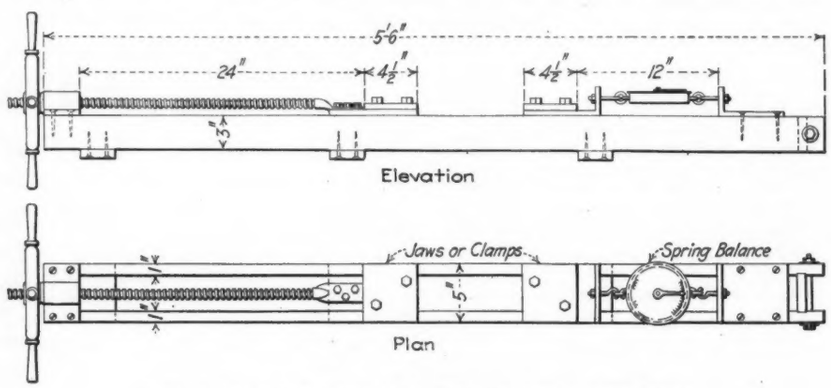


FIG. 1. DEVICE FOR MEASURING BELT TENSIONS

Belt carrying coal to boiler-room hoppers in power station, Cape Province:

Rubber belt, 16 in. wide.
Length between centers, 178 ft.
Angle of incline, 20°.
Elevation, 30 ft.
Provided with traveling tripper.
Belt carried 150,000 tons of coal.
Life, 7 years; at that time belt had deteriorated through cracking and perishing, due mostly to the changes of temperature between boiler-house roof and outside and to exposure.
Twenty tons per hour could be carried if steadily loaded.

Particulars of belts conveying ore at a local gold mine:

This was a balata belt, 5-ply, costing 9s. per ft., and installed to carry damp ore to the stamp mill on an incline of 18°.
Total length of belt, 750 ft.; width, 24 in.
Speed, 350 ft. per min.
Tonnage carried, approximately 50,000 per month.
Total tonnage, 1,200,000 tons.
Life of belt, 27 months.

Loading of Conveyor Belts

It may safely be said that we are getting away from the days when the smallest width of belt compatible with the tonnage to be handled was installed, and when belts were run at speeds up to and over 600 ft. per min. The

tendency nowadays, and a correct one, is to install a belt of ample width and run it at a speed of 100 to 150 ft. per min. In the case of belts used for sorting purposes a speed of 40 ft. per min. should not be exceeded.

The delivery of material to and from conveyors requires most careful consideration. Our ideas regarding the best methods are shown in the various diagrams. The chutes leading material to a belt must be arranged so as to deliver in the same direction as the belt is running, as in Figs. 25 and 26. On no account may a chute deliver at right angles to, or in opposite direction to, the run of the belt. The even loading and distribution on a belt is essential in order to get full capacity and good working conditions. If not correctly loaded, it will not run true and straight nor lie evenly on the

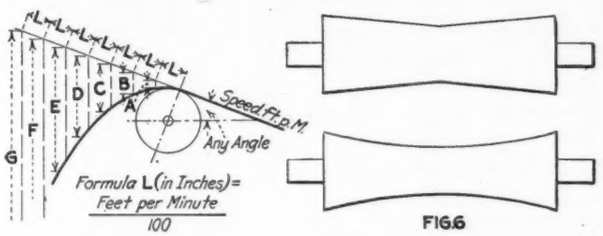


FIG.2

FIG.6

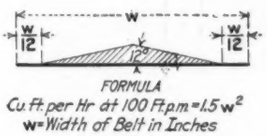


FIG.3

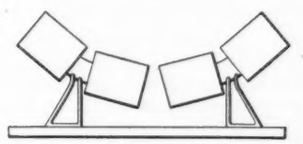


FIG.7

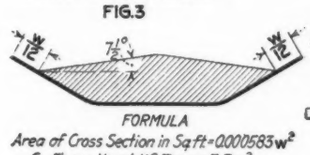


FIG.4

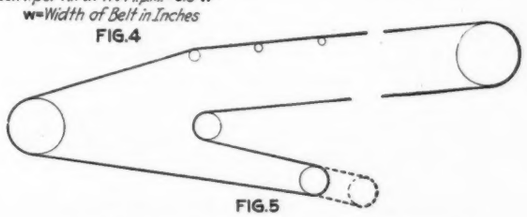


FIG.5

DETAILS OF TROUGHING CONVEYORS

idlers, but will swing from side to side and take on a snake-like motion which will destroy it in a short time. Chutes should be a few inches less in width than the carrying belt to allow of correct loading, and a tapering width should be strenuously avoided. A chute should deliver to a belt without causing impact, and delivery must take place between and not onto the idlers.

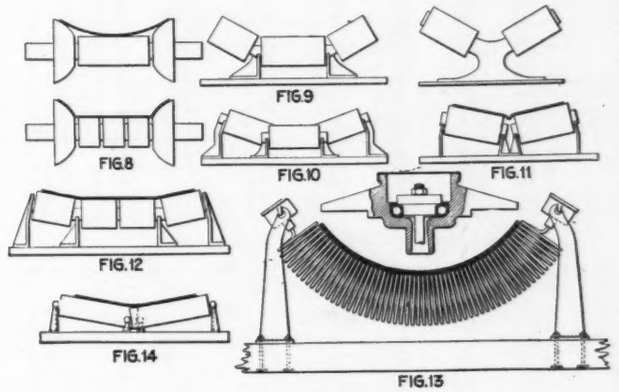
In America, which I think may justly be termed the home of conveyor belts, a progressive firm has designed and installed a method similar to the "Comet" feeder.

The delivery from a belt is of equal or even greater importance than that to a carrying belt. A bad form of chute has destroyed many conveyor belts, for if the chute is not properly made and placed, material may jam and cut the belt to pieces. Chutes wrongly placed require frequent renewal, and those delivering from one belt to another may destroy the second belt if badly arranged.

For the purpose of designing delivery chutes from belts, figures showing the actual delivery from various belts at different speeds are given, also an easy formula and diagram for obtaining the trajectory of delivery from any belt (see Fig. 2). Our ideas with regard to the placing of chutes are shown in Figs. 25 and 26, already mentioned.

Belt Scrapers and Cleaners

Dirt, chips and wet material have a tendency to adhere to the top side of all belts, perhaps more so in the case of balata than with rubber belts. As this side of the belt is the one which comes in contact with the return idlers it is desirable to have it as clean as possible to prevent wear of idlers and the accumulation of dirt under the belt. To keep the return side clean is a difficult matter, and particularly so when waste rock is carried by the belt on its return. A perfect belt cleaner has not yet been devised. If a brush is used, it gets clogged and refuses to move. A scraper of wood or belting catches the grit and wears out the belt surface. Sprays unaccompanied by scrapers only made matters worse, so that unless great care and attention is paid



TYPES OF IDLERS

to the running of any scraping or cleaning arrangements, they are better dispensed with in connection with ore handling. Fig. 18 shows a type of belt cleaner driven from head end of belt and arranged to tap the belt and so knock off the material clinging to the surface. Fig. 19 shows the construction of chutes, so that wear and tear may be minimized, by having a false bottom that

TRAJECTORY TABLE FOR CONVEYOR BELTS[1]

Delivery from Belts (See Fig. 2) Constants

	Decimals	Fractions		Decimals	Fractions
A	0.4284	7/16	I	39.0744	39 1/16
B	1.9296	1 15/16	J	48.2450	48 1/4
C	4.3416	4 11/16	K	58.3704	58 3/8
D	7.7184	7 23/32	L	69.4656	69 15/16
E	12.0600	12 1/16	M	81.5256	81 17/32
F	17.3664	17 3/8	N	94.5504	94 9/16
G	23.6376	23 5/8	O	108.5400	108 17/32
H	30.8736	30 7/8			

This formula holds good in all cases except when material being conveyed tends to stick to the belt, or is very light and easily deflected by the resistance of the air.

[1] Jeffrey Conveyor Co.

fills up with material which attains its own angle of repose. Guide boards used for the purpose of assisting the proper loading of a belt lead to great trouble and should be avoided.

Much thought and attention have been given to the design and manufacture of conveyor idlers, and many types have been evolved. Figs. 6 to 17 show various forms of idlers. Fig. 6 is essentially wrong in prin-

ciple, as is self-evident. The various peripheral velocities due to the increasing diameters cause an abrasive action, which quickly rubs the covering off any belt. Fig. 7 shows a 4-pulley idler and denotes the attempt to arrive at a better belt curvature; one disadvantage is the many roller edges which come in contact with the belt, and another is the additional number of bearings. Fig. 8 is the dishpan idler; this form soon cuts the belt, as is shown in the diagram giving loaded position.

At Fig. 9 is the usual type of idler, in which the cutting edge of the rollers is a disadvantage also the poor curvature of the belt. Fig. 10 shows a method of getting away from the cutting edges of the rollers by placing

CAPACITIES OF VARIOUS WIDTHS OF CONVEYORS OPERATING AT 100 FT. PER MIN. AND HANDLING MATERIAL OF VARIOUS WEIGHTS[2]

Flat Conveyor Belts (See Fig. 3)

Formula: Cu.ft. per hr. at 100 ft. per min. = $1.5w^2$, where w = width of belt in inches.

Width of Belt In.	Cross Section of Load, in Sq.Ft.	Cu.Ft. per Hr. at 100 Ft. per Min.	Cu.Yd. per Hr. at 100 Ft. per Min.	Tons per Hr. at 100 Ft. per Min. Weight of Material in Lb. per Cu.Ft. 25	50	75	100	125
10.....	0.025	150	5.5	1.9	3.8	5.7	7.6	9.5
12.....	0.036	216	8.0	2.7	5.4	8.1	10.8	13.5
14.....	0.049	294	10.9	3.7	7.4	11.1	14.8	18.5
16.....	0.064	384	14.2	4.8	9.6	14.4	19.2	24.0
18.....	0.081	486	18.0	6.1	12.2	18.3	24.4	30.5
20.....	0.100	600	22.2	7.5	15.0	22.5	30.0	37.5
22.....	0.121	726	26.9	9.1	18.2	27.3	36.4	45.5
24.....	0.144	864	32.0	10.8	21.6	32.4	43.2	54.0
26.....	0.169	1,014	37.5	12.7	25.4	38.1	50.8	63.5
28.....	0.196	1,176	43.5	14.7	29.4	44.1	58.8	73 5
30.....	0.226	1,350	50.0	16.9	33.8	50.7	67.6	84 5
32.....	0.256	1,536	56.9	19.2	38.4	57.6	76.8	96 0
34.....	0.289	1,734	64.3	21.7	43.4	65.1	86.8	108.5
36.....	0.324	1,944	72.0	24.3	48.6	72.9	97.2	121.5
38.....	0.361	2,166	80.2	27.1	54.2	81.3	108.4	138.5
40.....	0.400	2,400	89.0	30.0	60.0	90.0	120.0	150.0
42.....	0.441	2,646	98.0	33.3	66.2	99.3	132.4	165.5
44.....	0.484	2,904	107.5	36.3	72.6	108.9	145.2	181.5
46.....	0.529	3,174	117.5	39.7	79.4	119.1	158.8	198.5
48.....	0.576	3,456	128.0	43.2	86.4	129.6	172.8	216.0

Troughing Belts with Three Idlers (See Fig. 4)

Formula: Area of cross-section in sq.ft. = $0.000583w^2$; cu.ft. per hour at 100 ft. per min. = $3.5w^2$, where w equal width of belt in inches.

10.....	0.058	350	12.9	4.4	8.8	13.2	17.6	22.0
12.....	0.084	504	18.7	6.3	12 6	18.9	25.2	31.5
14.....	0.114	686	23.4	8.6	17.2	25.8	34.4	43.0
16.....	0.149	896	33.2	11.2	22.4	33.6	44.8	56.0
18.....	0.189	1,134	42.0	14.2	28.4	42.6	56.8	71.0
20.....	0.233	1,400	51.9	17.5	35.0	52.5	70.0	87.5
22.....	0.282	1,694	62.7	21.2	42.4	63.6	84.8	106.0
24.....	0.336	2,016	74.7	25.2	50.4	75.6	100.8	126.0
26.....	0.394	2,366	87.6	29.6	59.2	88.8	118.4	148.0
28.....	0.457	2,744	101.6	34.3	68.3	102.9	137.2	171.5
30.....	0.525	3,150	116.7	39.4	78.8	118.2	157.6	197.0
32.....	0.597	3,584	132.7	44.8	89.6	134.4	179.2	224.0
34.....	0.674	4,046	150.0	50.6	101.2	151.8	202.4	253.0
36.....	0.756	4,536	168.0	56.7	113.4	170.1	226.8	283.5
38.....	0.842	5,054	187.0	63.2	126.4	189.6	252.8	316.0
40.....	0.933	5,600	208.0	70.0	140.0	210.0	280.0	350.0
42.....	1.029	6,174	229.0	77.2	154.4	231.6	308.8	386.0
44.....	1.129	6,776	251.0	84.7	169.4	254.1	338.8	423.5
46.....	1.234	7,406	274.0	92.6	185.2	277.8	370.4	463.0
48.....	1.344	8,064	299.0	100.8	201.6	302.4	403.2	504.0

The figures given are for perfect loading arrangements; 25 % should be deducted for ordinary practice.

[2] Jeffrey Conveyor Co.

the center roller behind the inclined rollers. Fig. 11 shows the liability of the belt being cut if this type is used. Fig. 12 shows a four-roller idler to obtain good curvature of belt; idlers are also constructed with five rollers to attain this object. The number and position of bearings is a disadvantage. Fig. 13, in the endeavor to obtain good belt curvature an idler constructed of a spiral spring 5 in. diameter, with 2 coils per inch of width, has been proposed. The springs under the weight of the belt and its load stretch and sag to a smooth curve of approximately circular shape, and the belt bends to a troughed form in contact with and supported by the spring across its entire width. A pure rolling contact at all points is expected. I cannot say whether this type has ever been tried. Fig. 14 shows a type of idler with good features. It has good curvature, no cutting edges and few bearings.

At Fig. 15 is shown a strong and easily get-at-able type of ball bearing. Idlers fitted with ball bearings have come into use and are likely to supplant the older types of plain idlers. Some forms of ball-bearing idlers seem much too lightly constructed considering the material to be handled and the rough usage of gold-mining operations. Types of ball-bearing idlers so constructed that the pulley has to be cut to pieces in order to get at the ball race would seem to be a wrong method. The use of side-guard idlers or boards for the purpose of keeping a belt straight is quite wrong in principle and destructive to belts. Fig. 16 is Reddaway's patented arrangement to obtain good alignment of belt. Fig. 17

DATA FOR SELECTING SUITAB LE SIZE OF CONVEYOR[3]

Size of Belt, In.	Area of Normal Load, Cross Section in Sq.Ft.	Rated Capacity in Cu.Ft. per Hr.	Sized Material, Size of All Lumps, Cu.In.	Unsized Material, Size of Largest Lumps, Cu.In.	Rated Capacity in Tons per Hr. at 100 Ft. per Min. Speed Material Weighing 50 Lb. per Cu.Ft.	Material Weighing 100 Lb. per Cu.Ft.	Limit of Speed In Ft. per Min.
12	0.075	450	2	2	10	20	350
16	0.133	798	3½	4	17	34	400
20	0.208	1,248	5	6	27	54	450
24	0.350	1,800	6	9	40	80	500
30	0.469	2,814	8	12	62	124	600
36	0.675	4,050	10	15	90	180	700
42	0.919	5,514	12	18	122	244	725
48	1.200	7,200	15	20	160	320	750
60	1.875	11,250	18	24	250	500	800

Note. These figures are given as a general guide and must be followed with caution; the conditions under which the conveyor is loaded, whether continuous or intermittent, delivered by shovels from track hopper, whether material is wet or dry or has a tendency to roll—all these have an effect upon the capacity, and must be considered when selecting size and speed of belt.

IDLER SPACING, SPEED AND LOAD FACTORS[3]

Size of Conveyor	12 In.	14 In.	16 In.	18 In.	20 In.	22 In.	24 In.	26 In.	28 In.	30 In.	32 In.	34 In.	36 In.
Material weighing 25 to 75 lb. per cu.ft.													
Troughing idlers spaced, ft.	5½	5½	5½	5	5	5	4½	4½	4½	4½	4	4	4
Speed factor	.023	.026	.029	.046	.050	.056	.069	.069	.072	.082	.096	.106	.117
Load factor	.068	.068	.068	.075	.075	.075	.075	.075	.069	.069	.065	.065	.065
Material weighing 75 to 125 lb. per cu.ft.:													
Troughing idlers spaced, ft.	5	5	5	4½	4½	4½	4	4	4	4	3½	3½	3½
Speed factor	.020	.026	.030	.048	.052	.058	.071	.071	.075	.084	.098	.108	.119
Load factor	.068	.068	.068	.075	.075	.075	.075	.075	.069	.069	.065	.065	.065

Return idlers spaced 10 ft. apart. Top guide idlers usually spaced 45 ft. apart.

To find horsepower, in the preceding table, under proper spacing of idlers, find the speed and load factor.

Formulas:
Speed factor × conveyor speed in ft. per min. = Result I.
Load factor × load in tons per hour = Result II.
The sum = Result III.
Result III × length of conveyor in ft. = Result IV.
Result IV ÷ 1,000 = hp. at given speed and load.

If conveyor is inclined: Tons per hour × height lifted in ft. added to Result IV, and then ÷ 1,000 = hp. required.

If conveyor has trippers, either fixed or traveling: Add for each tripper the hp. as given below under proper speed, this result = total hp., add 15% for contingencies.

HORSEPOWER OF TRIPPER OF VARIOUS SPEEDS OF CONVEYOR[3]

	Size of Conveyor	12 In.	14 In.	16 In.	18 In.	20 In.	22 In.	24 In.	26 In.	28 In.	30 In.	32 In.	34 In.	36 In.	42 In.	48 In.
Fixed Tripper	Conveyor Speed in Ft. per Min. 100	.10	.10	.20	.30	.30	.40	.40	.40	.40	.40	.40	.50	.50	.60	.70
	200	.30	.30	.40	.50	.50	.60	.60	.70	.70	.80	.80	1.0	1.0	1.2	1.4
	300	.40	.40	.50	.70	.80	.80	1.1	1.1	1.2	1.2	1.3	1.5	1.5	1.8	2.1
	400	.50	.50	.70	.90	1.1	1.2	1.4	1.4	1.5	1.6	1.7	1.9	2.0	2.4	2.8
	500	.60	.60	.90	1.1	1.4	1.6	1.8	1.8	1.9	2.0	2.1	2.3	2.5	3.0	3.3
Traveling Tripper	Conveyor Speed in Ft. per Min. 100	.20	.20	.20	.30	.30	.40	.40	.40	.50	.50	.50	.60	.60	.70	.80
	200	.30	.30	.40	.50	.60	.70	.80	.90	1.0	1.0	1.0	1.2	1.2	1.4	1.6
	300	.40	.40	.60	.90	1.0	.90	1.3	1.4	1.5	1.5	1.6	1.8	1.8	2.1	2.4
	400	.60	.60	.80	1.1	1.3	1.4	1.7	1.8	1.9	2.0	2.2	2.3	2.4	2.8	3.2
	500	.70	.70	1.0	1.3	1.5	1.8	2.1	2.3	2.4	2.5	2.6	2.8	3.0	3.6	4.0

[3] Robins Conveyor Co.

shows the Johnstone idler, consisting of a number of pulleys of different diameters running free on the shaft.

Regarding the tensile strength of rubber conveyor belts, when you have obtained the actual hp. required for driving the belt, it is easy to find the actual working tension the belt has to stand. To obtain the actual pull

as compared with the useful pull the following figures may be used:

Bare single pulley	1.6	Tandem bare pulley	1.3
Lagged single pulley	1.5	Tandem lagged pulley	1.2

These figures may be safely used.

MAXIMUM ALLOWABLE TENSION PER PLY

4-ply = 23 lb. per inch per ply. 7- and 8-ply = 20½ lb. per inch per ply.
5-ply = 22 lb. per inch per ply. Over 8-ply = 20 lb. per inch per ply.
6-ply = 21 lb. per inch per ply.

The use of snub pulleys should be avoided if possible by giving the belt a long lead to the first return idler; if they cannot be dispensed with, they should be of large diameter, say 18 or 24 in. Head and tail pulleys should be of the largest diameter admissible. A pulley 5 in. diameter for each ply of the belt is the minimum, and 8 in. should be adopted if possible. Large pulleys increase the life of belts considerably by eliminating the heavy strain that is imposed when made to bend round a small diameter. In this connection an interesting point has been advanced by some makers of belts—namely, that belts should be constructed with an uneven number of plies, and instead of the usual 4, 6 or 8, it should have 5, 7 or 9 plies, especially in the steeper drives.

The theory advanced for the known fact that many even-ply belts have been known to open down the middle seam, while an uneven ply remained intact, was that with, say a 6-ply in passing over a small diameter pulley, the strain set up temporarily by the difference in distance from the center of the pulley to the pulley side and carrying surface of the belts, seems to center and have its greatest effect in or about the middle of the belt in thickness, this action causing three plies to remain more or less firmly cemented together in what might be termed the upper and lower halves of the belt, and whereas the frictioning between the upper and lower halves of 3-ply each is comparatively soon destroyed, or reduced in strength to such an extent that the third and fourth ply will come apart when the other plies and the rubber surfaces are in perfect condition.

An 8-ply belt which was put on pulleys 20 in. diameter within four months after installation was found to have separated in layers and into spaces two or three yards long along the whole length of belt.

The most usual form of tension end is the screw take-up, which requires careful adjustment. A method of obtaining an even and uniform tension is shown in Figs. 22, 23 and 24. Fig. 5 shows a poor form of take-up gear, which was necessitated owing to the under side of the belt being used to convey waste rock on its return.

The amount of take up usually allowed is 18 in. for belts up to 100-ft. centers, 24 in. for belts up to 200-ft. centers, and 36 in. for belts over 200-ft. centers.

The driving gear for a conveyor belt should be placed at the discharge end, so as to pull and not push the material along.

Angles and Speeds of Belts

It is not considered advisable to run belts at a steeper angle than 18° with the horizontal, although coal and material generally can be carried at an angle of 20° elevation if particular attention is paid to the loading, but this is not good practice.

Sorting belts should be run horizontal, or may be run at an angle up to 10° if elevation is necessary. Belts should not be made to change direction from horizontal to inclined in one piece. Where such an arrangement is necessary, two separate belts, one horizontal and one inclined, should be installed, as shown in Figs. 20 and 21.

Belts should be of ample width for the tonnage to be carried at comparatively slow speeds, say from 100

TABLE OF POWER CONSTANTS

Width of Belt, In.	C Power Constant	Hp. for Each Tripper	Width of Belt, In.	C Power Constant	Hp. for Each Tripper
10	0.55	¼	30	2.45	2
12	0.65	¾	32	3.15	2
14	0.75	1	34	3.35	2
16	1.05	1	36	3.55	..
18	1.35	1½	38	3.75	..
20	1.70	1½	40	3.95	..
22	1.85	1½	42	4.15	..
24	2.00	2	44	4.35	..
26	2.15	..	46	4.55	..
28	2.30	2	48	4.75	..

For conveyors under 50 ft. in length add 20% to horsepower obtained above; over 50 ft. and under 100 ft. add 10%; over 100 ft. and under 150 ft. add 5%. To the horsepower at the head shaft as obtained above there should be added an additional 5% for each reduction through chain, belting, or cut gears, and 10% for each reduction through rough gears.

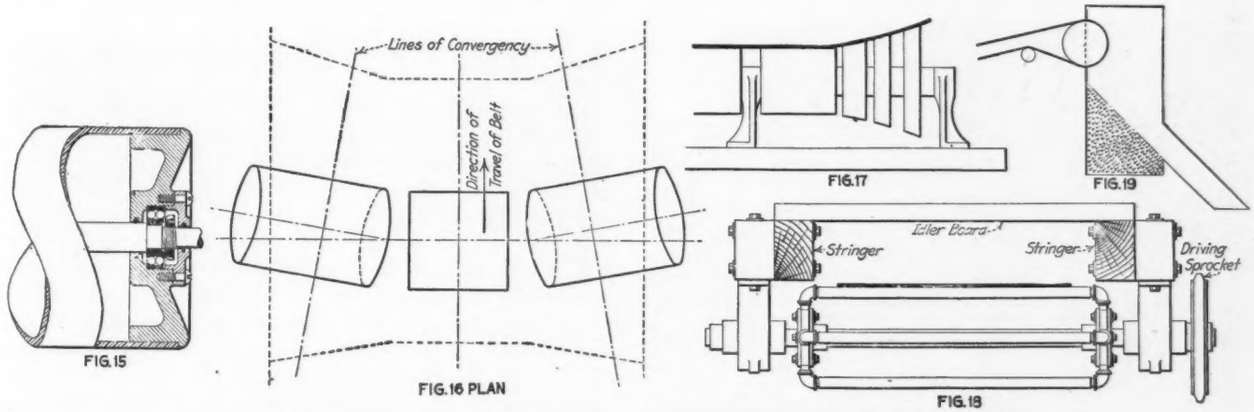


FIG. 15 FIG. 16 PLAN FIG. 17 FIG. 18 FIG. 19

SOME OF THE DETAILS DISCUSSED AS TO THE USE OF CONVEYOR BELTS

WEIGHT OF BELTS

Rubber Belts with 1-32 In. Rubber Cover, Plain or Stepped, for North British Rubber Belts

24-in., 2-ply = 2 lb., 4 oz. per ft. 24-in., 4-ply = 4 lb., 6 oz. per ft.
24-in., 3-ply = 3 lb., 10 oz. per ft. 24-in., 6-ply = 5 lb., 12 oz. per ft.

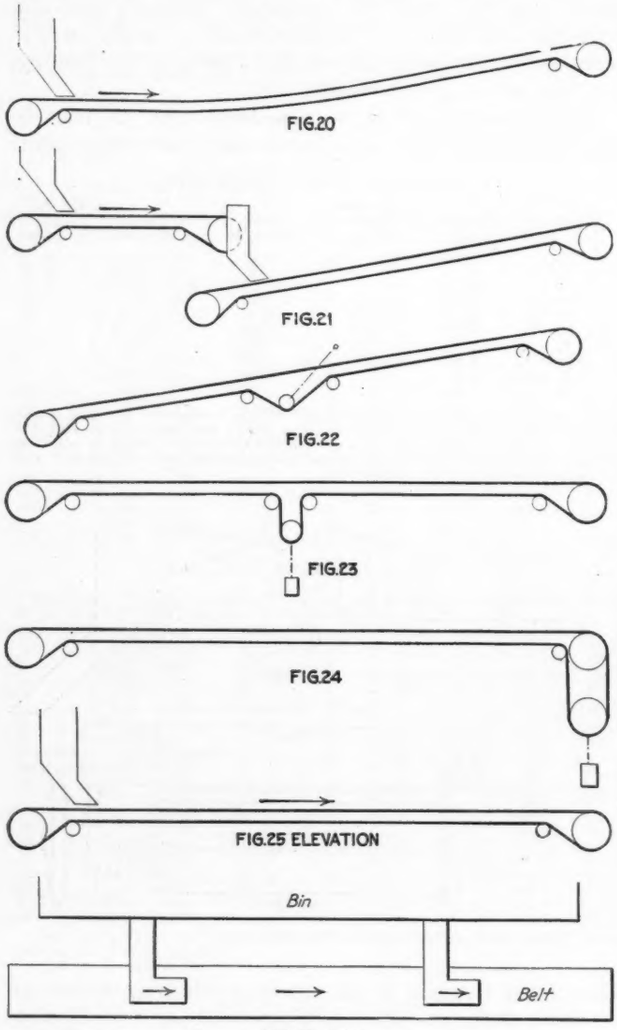
Lincona Belts (Balata)

	Lb.		Lb.
12-in., 6-ply, 100 ft. =	144	18-in., 8-ply, 100 ft. =	320
12-in., 8-ply, 100 ft. =	192	18-in., 10-ply, 100 ft. =	400
12-in., 10-ply, 100 ft. =	240	20-in., 5-ply, 100 ft. =	236
14-in., 6-ply, 100 ft. =	188	20-in., 6-ply, 100 ft. =	294
14-in., 8-ply, 100 ft. =	264	20-in., 8-ply, 100 ft. =	392
14-in., 10-ply, 100 ft. =	330	24-in., 5-ply, 100 ft. =	240
18-in., 5-ply, 100 ft. =	200	24-in., 6-ply, 100 ft. =	288
18-in., 6-ply, 100 ft. =	240	36-in., 6-ply, 100 ft. =	432

to a maximum of 200 ft. per min. For sorting belts 40 ft. per min. is about the maximum. To find the probable tonnage of coal or ore which a 100-ft. long conveyor belt will handle, multiply the width of belt in inches squared by 500.

Efficiency of Conveyor Belts

The efficiency of belts is usually taken at from 40 to 50% for inclined conveyors. Everything depends on the care and attention paid to the design and maintenance of any installation. The use of ball-bearing idlers and



ARRANGEMENTS OF CONVEYOR BELTS

proper attention in the running of belts should tend to increase the previously obtained efficiencies considerably. Formuals:

Approximate hp. required =

$$\frac{\text{lb. carried per min.} \times \text{elevation in ft.}}{16{,}500}$$

Capacity of belt:

Approximate tonnage carried per hour =

$$\frac{\text{width in inches}^2 \times \text{weight per cu.ft. material} \times \text{vel. ft. per min.}}{70{,}000}$$

Horsepower required (Jeffrey Conveyor Co.):

For horizontal belt, $Hp. = \dfrac{(CS + 2.33T)L}{33{,}000}$

For inclined belt, $Hp. = \dfrac{(CS + 2.33T)L}{33{,}000} + \dfrac{T \times H}{990}$

where

L = Length of conveyor belt in feet;
T = Load in tons per hour;
S = Speed in feet per minute;
C = Power constant from table.

Owing to existing war conditions it is quite impossible to give even comparative figures relative to the cost of various belts and their accessories. The cost of handling material varies considerably at different mines, and close figures are not always obtainable. The following are a few general figures: Transferring sand from collectors to treatment tanks by truck haulage, 1.978d. per ton; by conveyor belt, 1.22d. to 1.63d. per ton. Sand to dump, endless rope haulage, 4.236d. per ton; conveyor belt and boom, 4.118d. per ton; aërial rope haulage (Langlaagte Estate, length two miles), 3d. per ton; steam haulage (Simmer & Jack) 0.86d. per ton.

Belt Statistics

The tables giving the life, cost and tonnage carried of various belts have been compiled from a great number of returns, from which endeavor has been made to choose the most favorable examples available. The average cost of the belt only, per foot per month, for all classes of belt was approximately: For belts handling rock, 1s. 3d., and for belts handling sand, 7¼d.

The Gold Hunter Mill

The process in use at the Gold Hunter mill, Mullan, Idaho, is concentration, employing jigs, tables and flotation. The maximum capacity is 120,000 tons per annum. The total cost of the mill was $95,000, and the horsepower required to operate it is 300.

A total of 700 gal. of water per minute is used in the mill, which employs 26 men for its operation. Blake-type jaw and gyratory crushers are used with rolls and tube mills as auxiliaries. The ratio of concentration is 10:1, and the percentage of extraction averages about 80. No changes have recently been made in the mill, the Callow flotation system being used as customary, Pachuca tanks serving as mixers. These latter have not been discarded as has been the case at some other plants. Each Callow cell requires 9.6 hp. to supply it with compressed air.

The matter of concentrating the flotation tailings on tables has been considered and will probably be put into effect. A 30x6-ft. Dorr tank has been installed to thicken flotation concentrates ahead of the Oliver filter. There has also been installed a 30x6-ft. Dorr tank to thicken some dirty slime overflows that were escaping from the mill in several places. Another change of some importance is the removal of the quick-discharge device from the tube mills. Otherwise, the mill continues to operate after the same procedure described in the *Journal* of Dec. 25, 1915.

Zincfoil as a Substitute for Tinfoil is reported by Consul Harry G. Seltzer, at Breslau, Germany, under date of Apr. 27, who states that one of the Breslau tinfoil factories has succeeded in providing this substitute. The new product is not to be distinguished from tinfoil and is supposed to render the same services.

Don Luís Charme's Tremain Steam Stamp

By M. R. Lamb*

SYNOPSIS—Some details of the worries which come to consignees of mining machinery in South America; in this case, Don Luís Charme, who had a little mine of his own. The troubles of setting up the little steam stamp and getting it running were compensated by the successful results of its running and the satisfactory recovery made. Don Luís was treated to his first experience of that sinking feeling at the pit of the stomach when the noise of the mill suddenly stopped for the first time.

Sr. Charme is the owner of several gold mines in the Petorca mining district. His serious business is agriculture, but he likes to experiment with mining. Petorca is famous for its *past* production of gold. This is a peculiarity of practically all the gold and silver mines of Chile. At present there are but few gold and silver mines being operated, and the opportunities of getting hold of these old mines are excellent.

Sr. Charme had accumulated about 100 tons of hand-crushed, sorted ore, but as there is no custom plant near and as shipping and "returning charges" are high, he decided to put in as small a practical plant as he could find. About this time, by good luck I decided to use as an advertisement, a telegram received from Sr. Felipe Herrera concerning *his* Tremain, with the result that Sr. Charme investigated the Herrera plant and bought one like it. As things were a little slack and as I am a long way from the home office, it was possible to promise to set up the Tremain and show his mechanic how to run it. First payment was made, the order was cabled, and within eight days the little plant was on the cars, bound for New York.

When it comes to guaranteeing delivery, the best that can be done is a promise of New York delivery. The steamers from New York deliver at Panama or Colon without knowing or caring what ship will take the material on down the coast. And there is no way to hurry the reloading. And there is no way except by cabling to a friend, to find out if the material is there, and even he cannot tell you when it will be reshipped. There is no routine way of learning upon what ship the material will be sent from Panama, nor is there anyone to whom complaint can be made. The ship from New York has done its part in delivering at the Isthmus, and as there are several lines on this side, none of them is to blame. I have had a rheostat on the way 13 months now, and no one can give any information concerning it. But to get back to the Tremain.

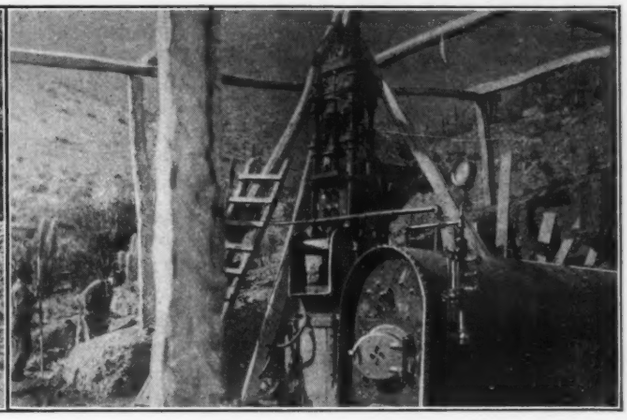
Upon being advised by our New York office of the steamers name and date of sailing, I gave the ship seven days to reach Colon and then cabled (reply paid, always) one of the steamship lines for name and sailing date of forwarding connecting steamer. This was promptly supplied, and Sr. Charme seemed to have an excellent chance of receiving his equipment in record time.

However, there is always something to interfere. I remember one shipment that was very urgent. Every effort was made—and successfully—to have a complete cyanide plant reach New York in ample time for a certain ship. The goods were received by the steamship company, but when the ship arrived at Valparaiso—no plant! Inquiry developed that it was coming on another ship of the same line a month later. Further inquiry of Captain Dexter, of the second ship, developed the fact that his ship was new and the plant was held back to favor the steamer, as she had little cargo.

But to get back to Sr. Charme's Tremain. When his ship arrived, there was no Tremain. After further cables it developed that the first ship decided not to bring the Tremain, so a later one was carrying it. The net result was a loss of three weeks.

While the shipment was being taken from Valparaiso to the mine (total unloading, agent, duties and other charges, $100) the bench was being cut in the hillside, a small dam was built to impound the water for the boiler and Tremain and a trail a hundred yards long

HAND-CRUSHED, HAND-SORTED ORE AT DON LUIS' MINE



THE TREMAIN STAMP AND BOILER PLANT DURING ERECTION

*Allis-Chalmers Mfg. Co., Santiago, Chile.

was cut from the mine dump to the mill site. The pit for the mortar block was 40 in. square and 10 ft. deep. The bench cut was contracted on a basis of 40c. per day for each of the men employed. As they are the same gold miners that taught the '49ers how to get gold in California, it will be seen that labor is cheap in Petorca. Carpenters receive 50 cents.

The cut was finished in plenty of time, and when the equipment arrived it was seized roughly and put into place as quickly as possible. As the town of Petorca, though inhabited by 1,500 souls and several foreigners, cannot supply nails, much less tools, Don Luís had us send him a real good and complete set of tools and supplies, which cost him $200. These might have been purchased in the States with the Tremain, but the difference in price would have been little, as American tools are carried by several hardware stores here in Santiago.

Pipe was required to bring water from the dam to the Tremain, besides the pipe sent with the equipment. We discovered *again* that English and American pipe threads are different. English thread is cut parallel to the surface of the pipe like bolt thread—American is taper; English pipe fitters put steam and water and gas pipe together with *string* in the threads, because it is not possible to make a tight joint otherwise. Besides this, the number of threads per inch and the shape of the threads are different. Taken altogether, a plant with two systems of pipe thread is some pleasant mixture. It is possible to *force* an English pipe into an American valve *once,* but both the valve and the pipe threads are incapacitated for subsequent use. The English merchant has had the start of the American in this question of pipe threads, so that as American manufacturers will not conform to English standards, confusion is bound to increase, especially as the U. S. S. P. Co. will and does supply any thread ordered.

Roberto and His Troubles

Roberto, the mechanic and mill man, had his first experience with American taper threads and pipe-graphite grease. In spite of positive instructions he was unconsciously trying to put the piping together with string and ravelings from sacks and from an old shirt. He was sure every joint would leak. (The plumber who installed all the pretty bathroom things in my house, made up every pipe joint with string and red lead, afterward burning off the excess with a torch. Even the nickel fittings are treated this way.)

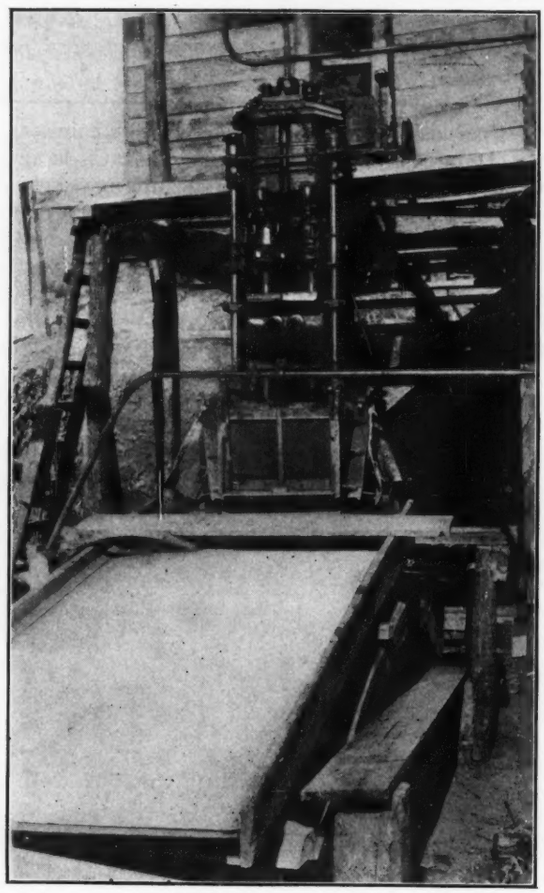
But to get back to the Tremain. We could not find a timber in Valparaiso to fit the instructions, so made the mortar block of three 12x12-in. sticks bolted together, with 3-in. planks nailed on the sides. The block was set in position, being first sawed off square. This sawing was done carefully, so that no planing was necessary. The "book" says to plane off the block, but fancy planing off the end of 18x36-in. block! This planing looked like a large order. It was easier to saw carefully and then set the block plumb and level.

The Tremain came on heavy skids in a thick oak box, all assembled, ready to set on the foundation. As boxing for the West Coast trade is specified "heavy enough to break anything that bumps it," it was no small job to unpack the shipment. The boxes were saved and serve for tool boxes and for supplies.

After the box was off the Tremain, it was skidded to its position back of the mortar block and stood upright. We had no chain block strong enough to lift it bodily, so the six men with three levers in the screen openings raised it four inches at a time, while I steadied it with a one-ton differential suspended on a tripod. This constant raising and blocking required over an hour to place the Tremain on the mortar block.

While this was going on, a carpenter was framing a set of crooked trees to serve as a bin and building. It was a delight to see him get his sticks out of wind without any help—and at 50c. per day of 10 hours.

The boiler is a 20-hp. locomotive type and was therefore ready to run as soon as it was connected to the water supply and to the Tremain. Hereafter I shall supply a 30- or 40-hp. boiler. Already Don Luís is talking of laying a steam line to the mine for a pump, of a small engine and concentrating table, and of a few hand drills and a compressor.



THE TREMAIN STAMP AND AMALGAMATING PLATE READY FOR OPERATION

The locomotive-type boiler is best suited to this type of plant because it is so easy to erect. In this case fuel costs $1.30 per ton of an excellent, free-burning resinous wood. It is brought in on burros from the neighboring hills, and for such a small plant the supply is everlasting.

When Saturday came, we were so nearly ready to run (and I was so tired and anxious to get back to Santiago) that we persuaded the men to work Sunday. Of course they had no supplies for Sunday, as they buy for a week at a time in Petorca. We agreed to supply the food for Sunday and Monday and to let them off Tuesday when the job was done. So we took coffee, sugar and bread for their breakfast, beans, bread and

wheat for lunch, and bread and tea for supper, and everyone was contented. At Braden the Chilean miners earn around $3 per day, and so have got into the habit of eating meat three times a day, but in the smaller camps and in the farming districts, meat eating is not the custom.

Only one holiday caught us. It seems that San Lorenzo is the gold miner's saint. No miner would think of working on that day, as something unfortunate was bound to happen. The workings would be dangerous, water would come in, the vein would pinch or evil spirits would be met in the mine. These evil spirits or *duendes*, are long-bearded dwarfs dressed in priests' raiment and are not at all pleasant to meet. There is nothing like them in the States. It would seem possible to argue that building a Tremain mill was not gold mining—but this argument failed.

While the piping between the boiler and Tremain was being connected, the bin was put together, and the ore packers filled it from the piles of ore at the mine, using rawhide bags.

Monday evening all was ready for a start. It was too late that night, but Roberto and I were up at 5 a.m. to make a trial before Don Luís and his friends arrived.

Roberto's First Lesson on the Plates

As there are no sleeping or eating arrangements at the mine, it meant a ride to and from Petorca four times daily. On Sunday it was agreed that we were to have roast turkey and all that goes to make a good lunch, provided the mill ran as promised. For this reason we got an early start. We warmed the stamp up a few minutes and then, too impatient to do this thoroughly, gave her full steam. The silvered copper plates had been beautifully dressed with mercury and a bit of cyanide, and Roberto got his first lesson in applying elbow grease to a plate. His lesson was fully as thorough as my first one was at Gold Cross in California, under old Adam.

When Don Luís arrived with his friends, we had been running an hour or so and even in that short time could show him some little points and splotches of amalgam on the lip plates. All the visitors, including the ladies, must needs hold the hose on the plate and examine the first gold produced in Petorca for many years.

The ore was already crushed by hand to one inch, and as it is a porous quartz, the Tremain fairly ate it up. We had toncap screens and they are partially suited to this mill. The amalgamation plate was set with a grade of three inches to the foot, in order to make the short supply of water reach as far as possible.

It used to take us a week of milling at Gold Cross to get the showing on the plates that we got here in four hours, so you can guess the grade of ore. The screen was rather too coarse, so the tailing is being impounded for cyaniding.

About the time the cook said lunch was on the table in a near-by hut, we felt that the Tremain would never stop. Roberto, who is running the plant now, was very anxious not to stop, so it was agreed that he would stay on at the mill while we lunched. While we were gone, the noise suddenly ceased, and Don Luís had his first experience of that sinking feeling at the pit of the stomach when the mill stopped. It took quite a while for us to discover that a bit of rubber packing had gone between the valve chest and cover. When that was replaced, we were off for a regular, uninterrupted run.

It required seven days, six men (one half-witted) and about ? dollars of total cost from the date of placing the order to the day the Tremain started, including tools, spares, pipe, dam, lumber and building and bin. With any luck in the mine, the mill will be paid for in two or three months.

Roberto is a good mechanic, but he had not seen a Tremain before. He has no trouble with it—at least, none that he tells me about, and he has gone through it thoroughly by this time. He has ordered spare shoes, dies and screens, and as Don Luís has arranged with him on a percentage basis of gross output, he finds means to work day and night.

Later—The plant has now been running for six months, and when the mine does not supply sufficient ore, waste which amalgamates ⅓ oz. has been used to keep the Tremain busy. An additional mill will probably be put in, and the same men will run it. The waste is even softer and finer than the mine ore, and the 24-hr. capacity at times reaches 18 tons.

Roberto wants finer screens, and we are sending him the finest listed. He has lost all faith in the hornspooners of that neighborhood and spends a little money occasionally on assays to check his amalgamation.

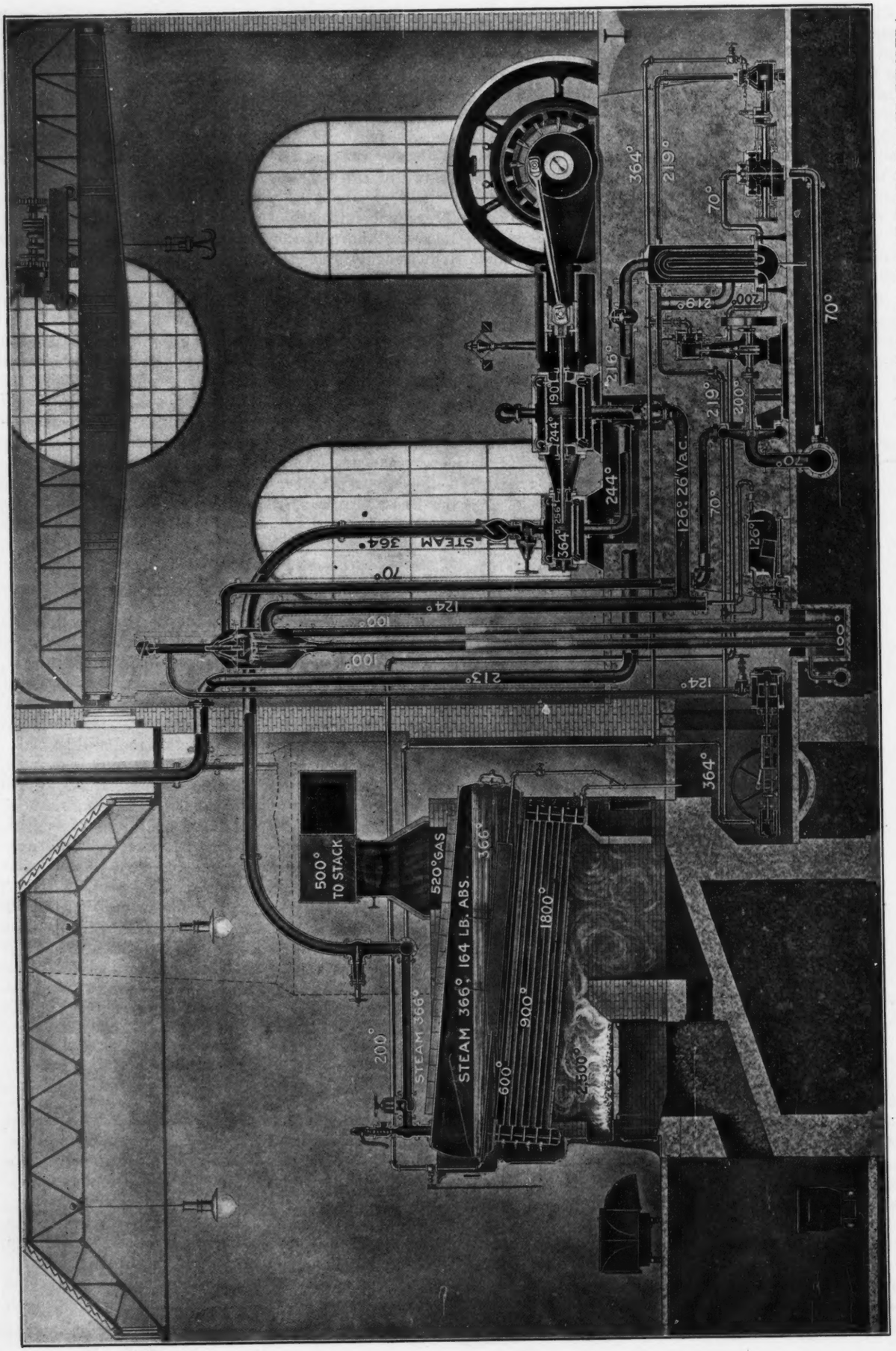
Flotation at Goldfield

The reports from Goldfield indicate that the flotation equipment now being installed, which includes 28 Callow cells, will be designed to replace, at once, or eventually, the cyanide treatment. It is pointed out that the use of flotation equipment treating 1,000 tons daily may save between $360,000 and $400,000 annually. This does not take into account the higher extraction that will be made. The avoiding of necessity for selective mining is also one of the important parts. Recent reports issued by the company indicate that development work is being resumed on the deeper levels, where large quantities of copper-bearing ore have been exposed. Heretofore, with treatment by cyanide, only ore carrying less than 0.5% Cu. has been milled; deep level ores carry more copper.

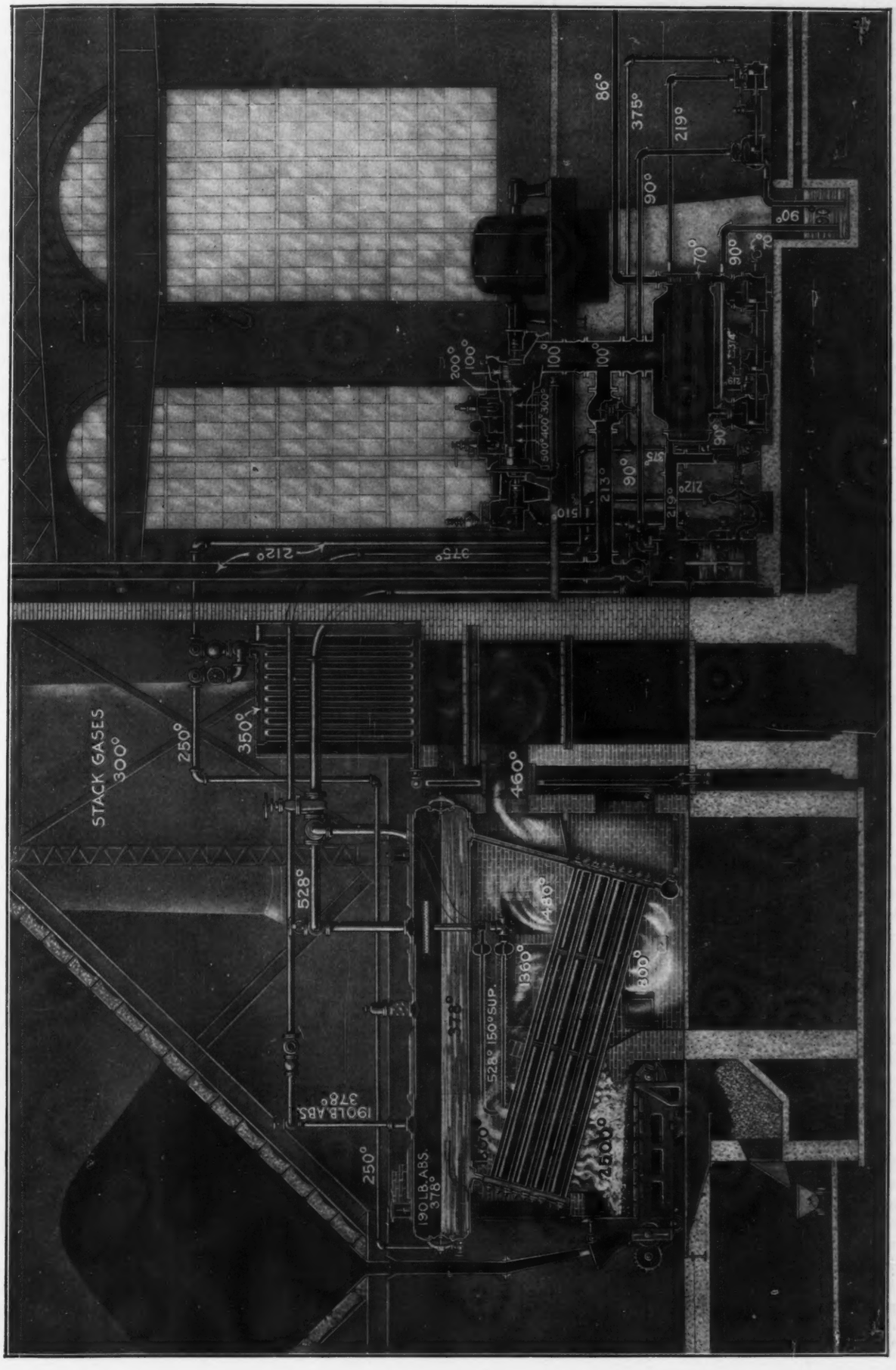
The ore treated during the past few months has been of low grade, much of it yielding a profit of less than $2 per ton, and the workings underground have been cleaned of everything that would yield the smallest profit. The limited extent to which the mines have been explored has already served to expose large deposits of gold-copper ore.

Power-Plant Steam-Temperature Diagrams

On the two pages following are published two sectional views of equipment and piping of typical reciprocating-engine and steam-turbine power plants, originally published in much larger size by our esteemed contemporary, *Power*. These diagrams show the temperatures throughout the power-plant equipment, from the firebox to the waste gases in the stack and from the feed water, through the boiler, through the engines and back to the hotwell. The difference between reciprocating-engine and turbine practice cannot be better portrayed than by a comparison of these two diagrams.



SECTIONAL VIEW OF EQUIPMENT AND PIPING OF A TYPICAL RECIPROCATING-ENGINE POWER PLANT, SHOWING TEMPERATURES OF BOILER GASES, AND TEMPERATURES AND PRESSURES OF STEAM DURING ITS COURSE FROM BOILER THROUGH ENGINE AND AUXILIARIES AND BACK TO BOILER



SECTIONAL VIEW OF EQUIPMENT AND PIPING OF A TYPICAL STEAM-TURBINE POWER PLANT, SHOWING TEMPERATURES OF BOILER GASES, AND TEMPERATURES AND PRESSURES OF STEAM DURING ITS COURSE FROM BOILER THROUGH ENGINE AND AUXILIARIES AND BACK TO BOILER

Cyaniding Copper-Bearing Ores

By Paul W. Gaebelein*

The ores of the Baker Mines Co. consist of quartz gangue carrying sulphides of iron, copper, lead and zinc. The gold is partly free, and a large proportion of the silver occurs as sulphide. These ores are treated in a twenty-stamp mill, with amalgamation, and the sands and slimes are treated separately, the cyanide treatment consisting of leaching, agitation in Dorr agitators, filtration over Portland filters, and zinc-dust precipitation. Owing to the great distance from the railroad and the consequent high haulage charges the ore is not concentrated, but cyanided direct.

The most objectionable constituent of the ore is copper, which occurs in quantities varying from 0.10% to 0.75%. It is in several forms, the principal ones being primary chalcopyrite, secondary chalcopyrite and carbonates. There is also an occurrence of bornite. An analysis of the mill heads is useless in determining what effect the

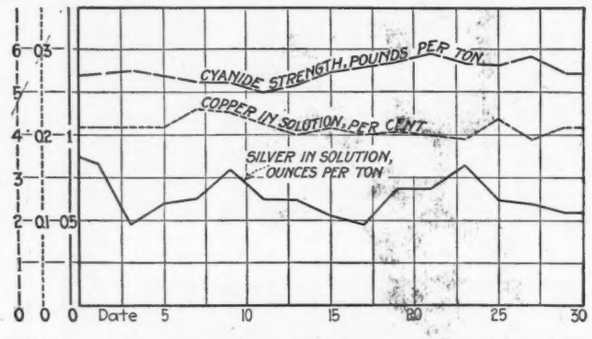


FIG. 1. COPPER, SILVER AND CYANIDE IN STRONG SOLUTION, AUGUST, 1915

copper will have because the primary chalcopyrite is only slightly attacked by the solutions, while the other forms of copper dissolve readily. In the operation of the mine and mill, therefore, it is necessary to keep careful watch on the ore being sent to the mill and to mix it in such a manner that the copper content will have the least detrimental effect.

Owing to the sulphide character of the ore a rather long leaching period is necessary to obtain a satisfactory extraction, and 5 days of treatment with an average strength of solution of 5.5 to 6 lb. KCN is found necessary. When the copper content becomes too high for economical treatment of the ore, it is manifested in two ways—first, by the rapid dropping off of the solution in cyanide strength and, second, by the reduction of the pregnant solution in silver content, a strong solution being necessary for good silver extraction. The solution naturally shows, also, an increased percentage of copper. Thus the effect of an increase in percentage of easily soluble copper in the ore is noticeable at once. The remedy is, first, to attempt to reduce the copper content in the ore and, second, to bring the solution back to normal strength. The latter cannot be done at once, but must be carried on gradually, depending upon the amount of copper present in the ore and how quickly this can be reduced.

In treating this ore the cyanide consumption is variable, ranging from 1.50 lb. KCN per ton to 4 lb. per ton, but by careful regulation of the ore it is kept to an average of 2 to 2.50 lb. The action of copper and its effect on the solutions is best illustrated by the accompanying diagrams, which are taken from the mill records. They are based on daily assays and anaylses of the solutions. Fig. 1 represents a normal month, the variations in silver and copper being due to variations in the grade of the ore. Figs. 2 and 3 represent October and November, 1915, during which period the copper in the ore became troublesome. About Oct. 16 the solution began to drop off in cyanide strength, and the addition of a greatly increased amount of cyanide did not serve to keep it from dropping still further. It was apparent, then, that an undue amount of soluble copper had appeared in the ore. It was inadvisable to increase the additions of cyanide further, as the cyanide was consumed rapidly and in consequence there was a still greater reduction of strength of solution, as shown by the curve in the

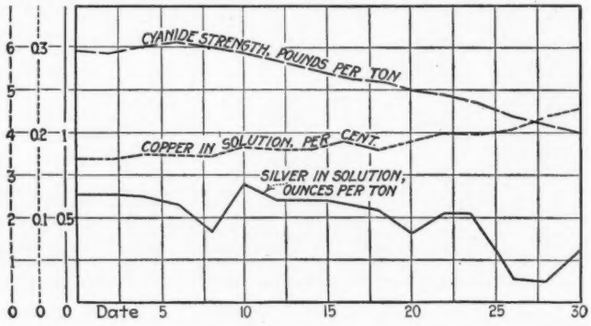


FIG. 2. COPPER, SILVER AND CYANIDE IN STRONG SOLUTION, OCTOBER, 1915

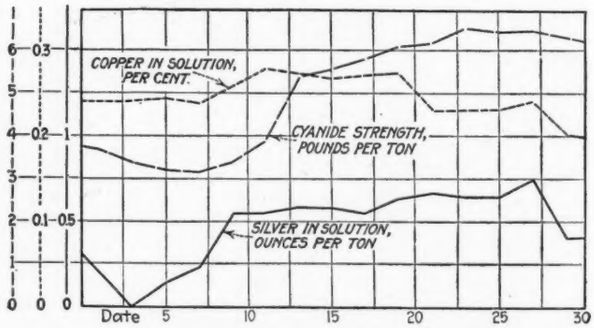


FIG. 3. COPPER, SILVER AND CYANIDE IN STRONG SOLUTION, NOVEMBER, 1915

illustration. At the same time, owing to the lower strength of solution, the silver was reduced to a very small amount. As will be noticed, the copper content of the solution also increased, in spite of the greatly lowered cyanide strength, showing the presence of a large amount of easily soluble copper in the ore. About Nov. 10 the increased additions of cyanide began to take effect and the solution rose rapidly in cyanide strength without any increase of copper content in the solution, showing that the copper of easily soluble composition had passed out of the ore. With the return to normal strength the silver returned to its normal amount in the solution. During the period that the high copper ore was passing through the mill, the cyanide consumption reached a figure of 5 lb. per ton, and even this amount did not serve to raise the solution to its normal strength.

*Mill superintendent, Baker Mines Co., Cornucopia, Ore.

Fig. 4 gives the curves for a period of 6 months. By reference to the latter part of the period the effect of the copper ore handled during October and November can be seen. The increased consumption of cyanide, coupled with the lower strength of solution and the lessened silver content of the pregnant solution, gives a graphic picture of the effect of copper in the treatment of the ore.

In the treatment of an ore of this kind it is essential that a complete daily record be kept of the solutions. This, coupled with the fact that there is a considerable variety of ore in the mine, makes it possible to work

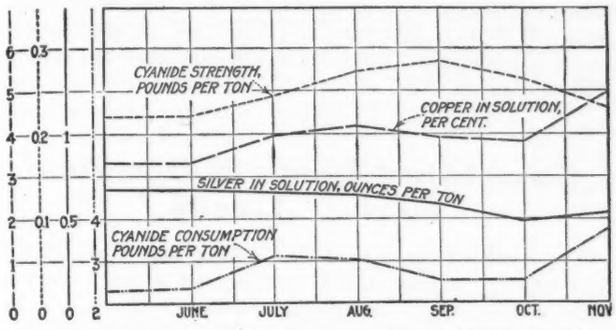


FIG. 4. RELATION BETWEEN CYANIDE CONSUMPTION AND CONTENTS OF SOLUTIONS

off gradually the difficult copper ores. The extraction obtained in the plant is normally from 85% to 86% on a grade of $20 to $25 per ton, but this is reduced when copper appears to a detrimental amount, as it did in the example cited previously. The silver extraction is affected to a much greater extent than the gold.

Hollinger Mining Costs

The following mining costs are from the 1915 annual report of the Hollinger Gold Mines, Ltd., Ontario, during which year 334,750 tons of ore was milled.

DISTRIBUTION OF MINING COSTS

Account	Labor	Stores	Per Ton of Ore Milled
General mining charges..	$6,970.91	$3,871.65	$0.032
Superintendence	12,785.25	.....	.038
Diamond drilling.....	5,792.24	7,676.22	.040
Crosscutting	10,490.19	13,728.63	.072
Shafts	8,006.43	6,433.99	.043
Drifting	27,355.66	31,454.96	.176
Raising	8,239.00	6,672.23	.045
Winzes	8,469.69	5,222.07	.041
Backfilling	302.79	291.59	.002
Timbering and repairs, shafts	6,511.29	12,339.67	.056
Stoping	109,359.07	116,911.60	.676
Scaling	8,552.34	.....	.026
Timbering and repairs, stopes	24,629.77	13,053.57	.113
Track laying	6,267.32	7,232.71	.040
Tramming and mucking..	103,685.66	1,256.16	.314
Pipe-fitting underground..	3,639.17	7,010.37	.031
Mine drainage.....	3,570.97	6,679.39	.031
Hoisting	37,065.77	15,641.93	.158
Landing and dumping....	4,424.63	749.69	.015
Drill repairs.....	2,471.67	15,729.49	.054
Sharpening steel.....	16,947.50	6,758.55	.071
Collecting steel.....	10,057.37	93.94	.030
Mine sampling.....	5,152.50	.....	.015
Assaying	1,117.40	670.57	.005
Change house.....	994.71	2,523.53	.001
Surveying	4,505.06	1,255.93	.017
Mine lighting.....	326.31	5,117.33	.016
Electric haulage.....	4,441.99	582.42	.015
	$442,132.66	$288,958.19	$2.183
Less credit for excess ore and waste rock broken..			.285
Net cost of mining			$1.898

RECAPITULATION OF MINING COSTS

Exploration	$5,792.24	$7,676.22	$0.040
Development	87,059.18	58,039.46	.433
Production	286,424.54	190,762.78	1.425
Deferred development.....	47,575.09	23,113.58	.211
Broken ore reserve.....	15,281.61	9,366.15	.074
	$442,132.66	$288,958.19	$2.183

The costs per ton milled are not absolutely correct in all details, as they include the cost of breaking 35,170 tons of excess ore and 42,424 tons of waste in development. A deduction of $95,800 from the total cost of mining is therefore made, to cover these items, making the net cost correct.

The following unit costs per foot are given as a matter of interest: Diamond drilling, including power, diamonds, labor, $1.60. Crosscutting, $6.40; shaft sinking, $42.32; drifting, $10.10; raising, $16.17; winzes, $39.20; stoping, $0.70 per ton; all including power, explosives and labor. Mucking and tramming, power and labor, $0.28 per ton of ore milled.

The Wrong Mill

By Charles Labbe*

Have you ever installed or run the wrong mill? I mean the wrongly designed mill with the wrong flow sheet, the machinery not suited for the ore or too antiquated for obtaining capacity—the mill built for the kind of ore that cannot be found in the district, or the ornamental mill; one erected where there is no ore.

The design of the mill is of capital importance, for on it will depend largely the success of the mine. It should be left to an experienced and reliable mill designer, not to a draftsman or amateur designer, for mistakes, however small, are expensive. A glance at the ore does not tell much as to the nature of treatment required, although in many cases this has been the only test made. A complete analysis of the ore should be made and its treatment decided after several mill tests made by disinterested parties. Be careful of the machinery seller. His language is convincing, and if you let him speak, he will tell you that his machines were made just for your ore. He will even name you some of the largest mining companies in the world using them, but he won't tell you the time and money they have spent in trying to fit the machines to the ore.

Use of Optical Tests Alone

I remember a mill where a glance at the ore had been the only test made and the owner decided it was concentrating ore. He once had seen jigs working and decided to install them. He also decided on roll crushing—why and how nobody knew. When the mill had run a short time, it was found impossible to make enough clean concentrates to pay, so it was transformed by replacing the rolls with Huntington mills, and the ore then concentrated on tables. This required a change of engines, so that the junk pile outside is larger than the mill itself.

In using the word junk I am not mistaken in my word. Years ago I used to believe that a machine, being only iron, could always be fixed to give good results, but now I have it strongly and deeply fixed in my mind that old machinery, worn out and tired, is only good for the cupola of the foundry. From my experience it is only lost time to consider it. When you have made all the repairs you thought necessary, you find that you did not make half of them, you have spent nearly the value of a new machine and the total result is that you have only trouble ahead. Mining machinery does not improve with age, especially if it has been through a fire. You can al-

*Mechanical engineer, Nelson, Nev.

ways get it cheap, but it has always proved the most expensive.

In milling, tonnage and extraction must always be kept in mind. We have seen a mill where the ore was sufficiently high in grade to pay for all mistakes and experiments, and while from a distance it looked like a success, we know that had it been treating a lower grade of ore, there would have resulted a disastrous failure. In these days of large bodies of ore of low grade that must be treated in mills of big capacity, nothing but the best and most suitable machinery should be used.

Newly Invented Machinery

A common mistake in small plants is the use of just-invented machines—too numerous are the gold-saving machines, from the dry concentrator to the mercury appliances, to catch gold that cannot be found by assay. Those inventors remind me of an old party who had a mine and mill for sale. The prospective purchasers agreed that if the ore plated an ounce, they would buy the mine at his price. Several tons of ore were milled, but they reported it did not plate an ounce. The old man told them that could not be for he himself had put in two ounces. Inventors are over-confident of themselves. Let someone else experiment with their machines—there are other good ones that have been tried and have stood the test. If you employ an engineer, it is up to him to find the right sort of machinery for your ore.

I have not yet heard of any mine that failed through having a stamp mill. Not that they are the most efficient crushers for the amount of power consumed, but I do not know of any other simple machine that will crush as efficiently from 1½-in. to 40-mesh, but they would do poor work crushing from 6-in. to 1-in. or from ¼-in. to 200-mesh.

The tube mill has become common in metallurgical plants. There are many kinds to choose from, and mistakes are being made in their selection. According to the diameter they must have a certain speed and a certain load. Like all other mining machinery, the tube mill that will grind all the different kinds of ore and give satisfactory results is still to be invented. I do not see why they have not been used for amalgamation to greater extent. They do not differ much from the clean-up barrel; of course they will flour mercury if the speed is too great and the pulp too thin.

A mill should be compact but not too crowded. Light must be plentiful day or night; the floor should be of concrete draining toward a sump where the runovers, leaks or sweepings can be saved. A good board floor often needs repairing, and if the boards do not join perfectly there will be much loss through the openings. The dirt floor is too expensive in the long run—muddy when wet, dusty when dry and anything small falling upon it is lost.

Too often a mill is designed with insufficient power, there being a great difference between the theoretical formulas and the actual power required. Too many times the power unit is bought as small as possible and when the pulleys are placed on the shaft and the engine connected with belts, it is found that the engine is overloaded, and then the operator is surprised that the shafting gets out of alignment, that boxes heat and that the bearings are rapidly worn and rendered useless. To keep up the speed, the engine must be forced and the boiler pressure raised, when the remedy is a larger engine.

From personal experience I can include dry mills in the classification of wrong mills, and I have yet to see one of them working right. Most of them have plenty of elevators in their flow sheet. This, I supose, is for aëration of the pulp or dusting of the premises. There is always such a dust that the belts are continually slipping and the shaft bearings are doing lots of grinding. The dry mills are successful in one way—sending men to the hospitals.

The management of a mill should not be given to one of your relatives who failed on a farm or in business; but like the mine manager, get a man with a few gray hairs, a training and a reputation as a successful millman. With the right man in charge and an assay office, you will soon know whether or not you have the wrong mill and much good may it do you then.

Cyaniding Costs at Douglas Island, Alaska

The Alaska Treadwell, Alaska United and Alaska Mexican mines, Douglas Island, Alaska, run a joint cyanide plant to treat the concentrates recovered, which in 1915 treated 19,177 tons for the Alaska Treadwell, 4,769 tons for Alaska Mexican and 11,556 tons for Alaska United. Costs were as follows on a total of 35,502 tons treated:

COSTS PER TON

	Grinding	Dissolving	Filtering	Precipitation	Refining	Total
Direct Labor:						
Operating	$0.175	$0.208	$0.145	$0.084	$0.174	$0.786
Repair	.021	.010	.035	.009	.028	.103
Supervision	.020	.020	.020	.020	.019	.099
Clerical	.007	.007	.007	.008	.008	.037
Total direct labor	$0.223	$0.245	$0.207	$0.121	$0.229	$1.025
Direct Supplies:						
Cyanide	....	$0.476	....	....	....	$0.476
Lime	....	.049	....	....	....	.049
Pebbles	$0.116	....	....	....	....	.116
Zinc dust	....	....	....	$0.228	....	.228
Precipitation cloth	....	....	....	.010	....	.010
Filter cloth	....	....	$0.031	....	$0.010	.041
Lead acetate	....	.044	....	.019	....	.063
Fluxes	....	....	....	....	.025	.025
Sulphuric acid	....	....	....	....	.023	.023
Filter paper	....	....	....	.010	.002	.012
Miscellaneous supplies	.014	.013	.004	.005	.028	.064
Total direct supplies	$0.130	$0.582	$0.035	$0.272	$0.088	$1.107
Subsidiary Accounts of Mixed Labor and Supplies:						
Building repairs	$0.001	....	....	$0.001	....	$0.002
Electrical repairs	....	$0.002	$0.001	.001	....	.004
Mechanical repairs	.033	.010	.007	.006	$0.032	.088
Electric power	.216	.010	.005	.012	.010	.253
Steam heat	.012	.013	.007	.004	.002	.038
Compressed air	.015	.012	.019	.012	.020	.078
Water	....	....	.013	....	....	.013
Train service	....	....	....	....	.001	.001
Assaying	....	.040	....	.021	.027	.088
Fire insurance	.008	.008	.009	.008	.008	.041
General expense	....	....	.001	....	.001	.002
Interest	.102	.101	.101	.101	.102	.507
Seattle office expense	....	.001	....	....	.001	.002
Fuel oil	....	....	....	....	.005	.005
Total mixed labor and supplies	$0.387	$0.197	$0.163	$0.166	$0.209	$1.122
Total cost	$0.740	$1.024	$0.405	$0.559	$0.526	$3.254

RECAPITULATION

	Cost per Ton
Grinding	$0.740
Dissolving	1.024
Filtering	.405
Precipitation	.559
Refining	.526
Total	$3.254
Labor	$1.025
Direct supplies	1.107
Subsidiary accounts	1.122
Total	$3.254

Flotation of Flour Gold

By Ralph W. Smith*

SYNOPSIS—In treating an ore containing lead, silver, zinc and gold, gravity concentration failed to make a salable product. Flotation was tried, and it was determined that by floating the slimes and treating the coarse portion by gravity and electrostatic separation, a thoroughly good result could be obtained.

Not so long ago there arose an interesting question in the treatment of a difficult ore which presented a common but undesirable problem. In the early history of the mine the ore ran high in gold and silver. Later, mixed sulphides of zinc, lead and iron became dominant. The first concentrating mill of modern design was erected about three years ago and succeeded in saving, to a certain extent, the zinc, iron and lead sulphides, but the gold and silver recovery was not satisfactory. This mill was treating ore of an average assay of 0.3 oz. gold, 2.5 oz. silver, 5% lead, 8½% zinc, 3½% iron and 0.5% copper. The gold was free and so fine that panning would not show a color. No hand specimens of gold were ever seen in the crusher feed, although occasionally a small piece was caught on the jig screens. Since the gold was fine, it was necessary to grind the ore very fine to liberate for concentration. Tests of cyaniding showed that treatment to be impossible commercially. Since fine grinding caused high slimming loss of the sulphides, the designers were literally "between the devil and the deep sea," and they chose a middle course.

Difficulties of Gravity Concentration

After grinding to 8-mesh, as much sulphide as possible was removed on Card concentrators and one Harz jig. The tailings from this treatment were reground to minus 30-mesh, washed over amalgamating plates, and reconcentrated on Card concentrators. At various times this scheme was alternated by using carpets in place of the plates, the free gold from the first riffle on the table being amalgamated in an arrastre. The simplified flow sheet indicates the source and disposal of the slimes. The high maintenance cost of the slimes concentrators, together with the large amount of floor space they occupied and the low saving they made, rendered this arrangement undesirable.

The difficult problem, however, still remained. The zinc concentrates from the tables were unsalable, since they assayed 0.75 oz. gold, 5 oz. silver, 10% lead, 33% zinc, 10% iron, 2.2% copper and 11% insoluble. In order to raise the percentage of zinc in the concentrates, the Huff electrostatic separating system was employed. A plant was erected that would treat all the zinc concentrates from the wet mill, and under these conditions the saving did not exceed 55 to 65% on any mineral. With such a loss it was natural to seek a process that would make a better saving. Flotation was suggested, and since a few rough preliminary tests gave promising indications, a systematic campaign of testing was inaugurated.

The early tests were run on the entire mill tailings, coarse and fine. They showed that a small quantity of salable concentrates could be made, but the tailings operated upon were so lean that a 90% recovery of all the minerals of value did not justify an expensive installation. The average feed for these tests was minus 30-mesh and and assayed 0.12 oz. gold, 2.3 oz. silver, 2% lead, 0.3% copper, 1.5% iron and 3.5% zinc. From this feed froth concentrates were recovered that assayed 0.5 oz. gold, 2.8 oz. silver, 3.1% copper, 10.1% lead, 12% iron and these tests weighed heavily against an installation, operating under these conditions. Acid would have necessitated a more costly plant, more floor space, more difficult operation and additional boilers for generating steam, besides which the cost of acid alone would have been almost prohibitive.

Floating the Slimes Portion

The plan of testing the entire mill tailings was abandoned, and the testing was confined to the slimes alone. A small amount of clean lead and a slightly greater amount of zinc was made from these slimes by the gravity treatment. The latter was dirty and had to be recleaned on another table, riffled especially to treat the slimes. The accompanying table shows some results obtained by this arrangement.

RESULTS FROM TREATMENT OF SLIMES ALONE

	Au, Oz.	Ag, Oz.	Pb, %	Zn, %
Feed	0.14	2.3	4	6.3
Lead concentrates	3.00	8.8	38	15.0
Zinc concentrates (to be recleaned)	0.70	6.0	12	18.0
Zinc concentrates (cleaned)	0.35	7.0	8	36.0
Lead concentrates (from recleaning table)	2.00	9.0	40	10.0

The slimes concentrators received a total of 30 tons of feed each day, of which 90 to 95% would pass a 200-mesh screen. The first series of flotation tests on these slimes was made with acid and heat. All normal variations of testing were tried, and some very fair products were obtained. A saving of 80% was common on all the minerals, and inasmuch as this feed was richer than in the tests of the entire mill tailings, the concentrates obtained per ton of feed increased also. However, calculations showed that the cost of acid was still a serious item. About this time certain tests disclosed the possibility of simplifying and cheapening the process to a considerable extent. The important changes embodied in this new set of conditions were the elimination of acid, heat and any considerable thickening of the pulp. The products formed under these conditions assayed 0.65 oz. gold, 12 oz. silver, 18% lead, 35% zinc, low iron and 4% insoluble. This assay shows that there was still further treatment to be made on this concentrate to separate it into salable products. The high percentage of lead in the concentrates indicates that a fair separation might be expected. Furthermore, in the tests the froth was not hard to break up.

These tests were so promising that construction was started on the commercial unit, and from the day the feed was turned on, better results were obtained than in the testing. The froth concentrates, as removed from the separator, were washed with clear water to a Wilfley table. The table classified the relatively coarse lead and zinc and made a perfect separation of them, but had very little effect on the remaining fine slimes. The coarse lead and zinc products were heavy enough to settle and were easily

*1845 Grant Ave., Denver, Colo.

dried and handled. The difficulty was found with the fine products. The slimes concentrates were pumped into a settling box 14x8x2 ft., and the clear-water overflow was conducted back to the flotation machine. To facilitate unloading this settling box, it was lined on the bottom with $\frac{1}{16}$-in. iron. In order to dry the products, a 2-in. steam line was laid on the iron bottom, with the coils far enough apart to allow a shovel to pass between. Steam at boiler pressure was used in the coil. The concentrates were dried only sufficiently to allow them to be stacked. A list of assays and tonnages is given in the accompanying table, showing how satisfactory the results were, particularly when compared with those obtained by the former test.

One of the first things noticed in the operation of the flotation machine was the fact that the free gold floated. The greatest gold values were in the first riffles of the Wilfley table, although the lead content extended over many more than did the high gold value. It was also shown positively that the lead did not contain any marked amount of gold. At times there was a small accumulation of gold on some spots of the table that had become greasy, and then the flour gold could be easily seen. Since the primary object of this flotation installation was to save the zinc and lead, the gold recovery was rather astonishing. Assays showed that much cleaner gold tailings were being made than by any other machine in the mill. The percentage saving of gold reached about 85.

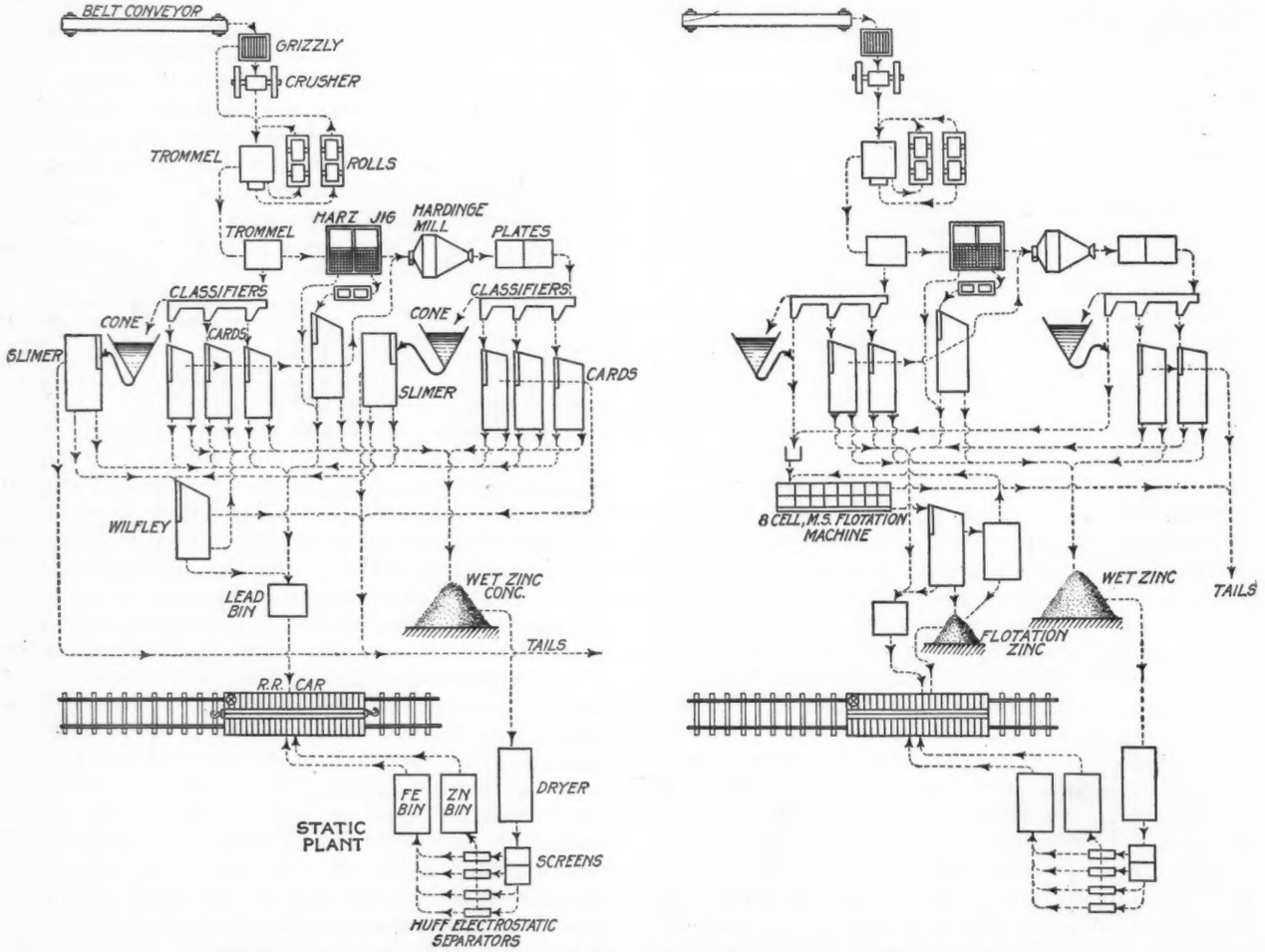
RESULTS FROM FINAL TREATMENT SYSTEM

Sample	Tons per 24 Hr.	Au, Oz.	Ag, Oz.	Pb, %	Zn, %	Fe, %
Flotation feed	30-35	0.14	2.5	3.0	5.5	1.0
Flotation tailings	28-30	0.03	0.8	0.8	1.5	..
Flotation froth (total)..	4-5	0.65	10.0	15.8	36.0	..
Flotation zinc (coarse), after table treatment.	2-3	0.50	9.0	5.0	54.0	4.0
Flotation zinc (fine) after table treatment.	1-2	0.50	12.0	11.0	40.0	5.8
Flotation lead, after table treatment	½-1	3.40	11.0	75.0	5.0	..

Advantages of the Flotation System

After noting the work of this machine, it is interesting to observe the numerous advantages and peculiar adaptability of flotation at this mill. The machine cost approximately $1,000 total, including the material, labor and designing. The peculiar advantages of flotation here are that no acid is used, no artificial heat, no additional pulp-thickening devices are necessary, the froth is easily broken down after removal from the machine, no classification is necessary before concentrating on the tables, and the saving on all valuable slimes contents is raised from 20% to 75 or 80%.

In addition the process is very simple in operation, it produces better products than were ever before possible at the mill, and no slime losses in dust occur. The static plant was relieved of undesirable slimes, and there was no royalty to pay, as with the static process. But one man per shift was required to operate the plant, which will run successfully on a lean-slimes feed. Not only are the actual mill results extremely favorable but there are



THE MILL FLOW SHEET BEFORE AND AFTER THE CHANGE TO FLOTATION

other considerations that tend to make the whole property more valuable. Among these facts may be mentioned: The impounded tailings dump of approximately 50,000 tons carrying gold, silver, zinc and lead, which can be retreated at some future date; lower grade ore can be sent down from the mine, as the recovery of concentrates per ton of feed is higher with the flotation installation; many tons of low-grade ore from the mine dump can now be profitably treated; and last, the possibility of radical changes in the milling system are open, which changes might result in lower treatment costs, better products and higher recovery. This might be accomplished by laying more stress on the flotation and giving less work to the static mill.

It is only to be regretted, as is the case in many other mills, that the process was not applied earlier in the operating history of the company, thus eliminating the steady losses that have been going on which cannot ever be recovered. Although this installation was in the experimental stage, it actually paid for itself and the test in two weeks of operation. Inasmuch as the installation demonstrated beyond a doubt that flotation can be used commercially to float gold, this plant has shed further light on modern milling practice, which will be welcomed by the engineering fraternity.

New Type of Tube-Mill Lining

By A. J. Weinig*

A new system of tube-mill lining has been devised and put into use at the mill of the Liberty Bell Gold Mining Co., at Telluride, Colo. Hard cast-iron ribs are laid with the regular courses of silex blocks, greatly increasing the life of the lining as a whole. A lining in a 5x22-ft. mill, containing seven rows of ribs, or one rib for every four rows of blocks, gives a life of 2 yr. and 7 mo. of continuous operation. In all our 5x22-ft. mills, we have placed 10 rows of ribs, or one rib for every three rows of silex blocks, and to all appearances our expectance of a life of three years will be reached.

The material used in lining a 5x22-ft. mill includes 900 silex blocks averaging 4½x5x8½ in. and weighing approximately 13 lb., also, 19 cu.ft. of portland cement, 19 cu.ft. of clean sand and 10 rows, or 50 pieces, of hard cast-iron ribs. These ribs are given a taper, measure 1¾x2x4½ in., and are 47½ in. long. They weigh approximately 110 lb. each. They are cast in Telluride, since the local foundry provides the best hard iron that we have been able to obtain.

Two picked men line the mill in three shifts. The lower half is lined in one shift. Live steam is then turned in for 8 hr., and the mill is allowed to cool by draft for 8 hr. more. Next the mill is given a quarter-turn, and one-quarter more of its lining is put in, followed by the same heating and cooling. On the third day the lining is completed, and it is afterward steamed for 12 hr. loaded with pebbles and then cut into service.

Where the cement is uncertain or slow setting, or where it is necessary to use it on minor repairs, soda ash is added to the mortar. This cement mortar sets rapidly and allows the mill to be put into use in 8 or 10 hr. The ribs are laid in mortar only, and no bolts are used in the lining. Experience has not developed any difficulties in holding the ribs or the lining by this method. No timbering is used in putting in the lining. The system seems to us to be advantageous from all points of view and will probably continue to be our standard practice.

*Mill superintendent, Liberty Bell mine, Telluride, Colo.

Dewatering Table-Sands and Concentrates

By L. A. Delano*

In the Bonne Terre mill of the St. Joseph Lead Co. the Wilfley tables have been riffled with Butchart riffles during the last six months. This has enabled the flow sheet to be greatly simplified and has resulted in removing the multiplicity of launders required to carry tailings and concentrates.

The table and jig tails were formerly run into a concrete tank in which a shovel wheel revolved, dragging the dewatered chat upon a belt conveyor, the shovels on this wheel containing holes for draining the water. The objectionable feature of this method of dewatering was that the sands did not settle enough and a large tonnage was carried by the overflow into the mill race and settling ponds. This made it necessary to sluice the race and ponds periodically to remove the sand, consequently using a large amount of water and labor.

A small wooden cone was installed over the chat belt for experimental purposes, and the tails from two Butchart tables were run into it. The sands settled rapidly, giving an overflow containing nothing over 150-mesh material. The spigot discharge to the chat belt averaged about 31% moisture. This was as good as the chat wheel gave on this material and showed that the water in the race could be kept free from sand.

In order to handle the necessary tonnage of sands, two 6-ft. steel Caldecott cones were placed over the chat belt. The tailings from two table sections were diverted to one Caldecott cone, giving approximately 400 tons of minus 2-mm. sand as feed. The overflow from the cone was free from plus 150-mesh material. The dewatered sands from the spigot discharge averaged from 28 to 30% moisture and were easily carried on a conveyor belt with a slope of 2.8 in. per ft. The sand settled rapidly in the cone, a constant level being maintained about 2 ft. below the overflow. Very little attention is necessary, there being no mechanical operation in the cone. The tonnage of tailings being fairly constant, the chat-belt man easily takes care of the slight adjustments due to any variation in load.

The concentrates (galena) from the jigs and tables were formerly cleaned in screw drags, the coarser sizes going to the mineral conveyors and then to cars. The sands and fines in the concentrates washed over the tail of the screws and were settled in tanks and shipped as slimes. The concentrates are now recleaned on Butchart tables, the clean galena being sent to a 6-ft. Caldecott cone. It settles rapidly, the overflow being perfectly clear even when the cone is two-thirds full. The concentrates are discharged through the bottom gate to the mineral conveyor. The moisture content averages 11%, which later drains to about 4 or 5% in the cars before reaching the smeltery. The discharge is operated intermittently as the tonnage varies too much to set the spigot gate at

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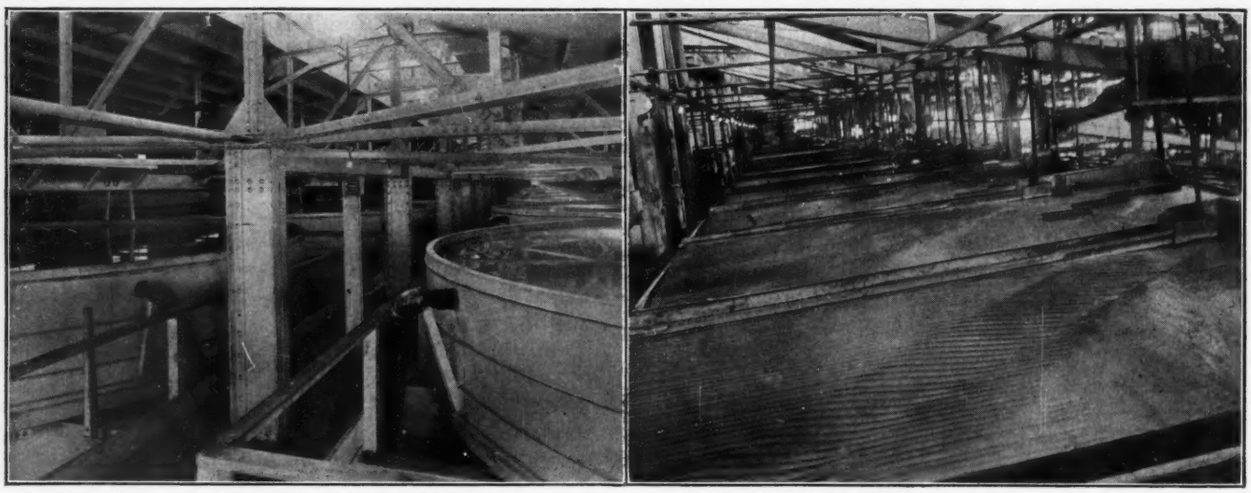
any given opening. However, it has not been difficult to operate, the mineral loader keeping a close watch on it so the cone will not become too full.

These cones have given better results than any other form of dewatering device and have the advantage of being purely gravity devices. There are no chains or scrapers to be broken or worn out as in chain drags, and no power is required.

Concentration at Anaconda*

On Jan. 25, 1916, the last section of the remodeled concentrator of the Washoe Reduction Works, Anaconda, Mont., was placed in commission. Water concentration has been retained for everything above 2 mm. in diameter, this being the maximum size of material sent to Hardinge mills for regrinding, and the product of the Hardinge mills is treated by the Minerals Separation flotation process. The concentrator consists of eight sections, each having a capacity of 2,000 tons of feed daily or, allowing for repairs, etc., a total average capacity for the entire mill of 15,000 tons.



INTERIOR OF THE CONCENTRATION PLANT AT ANACONDA, MONT.
To the left is the Dorr-thickener installation, and to the right the Wilfley tables equipped with Butchart riffles

In the crushing department there is no essential change, and the Harz jigs and upper tier of Evans jigs are as before. The two lower tiers of Evans jigs have been taken out and one set of 18 Wilfley tables, with Butchart riffles, substituted. These tables are roughers, and here ends the water concentration.

POWER REQUIRED IN MILL OPERATION

	Hp.
Feeding and coarse crushing	125
Roll crushing	220
Jigging	60
Screening	37
Conveying and elevating	237
Table concentration	25
Fine grinding	655
Flotation of sand and slime in mill	426
Dewatering slime pulp	3
Flotation of slime in slime division	109
Dewatering flotation concentrate	25
Sampling and assaying	1
Total	1,923
Tonnage daily	2,000

Next come the Hardinge mills, replacing the Huntingtons, but they grind much finer. The discharge of the Hardinge mills goes to three Minerals Separation machines in each section, while the slimes from the upper part of the mill (removed in the overflow of Anaconda classifiers) is treated in a fourth Minerals Separation machine after being thickened to 16% solids in a 28-ft. Dorr thickener. The remainder of the slimes, together with the 1,000 tons daily from an old dump is treated in a special slimes-flotation building fitted with 20 Minerals Separation machines. The concentrates from all the Minerals Separation machines are transferred by launders and elevators to 50x12-ft. Dorr thickeners, and thence to Oliver filters. The overflow of the thickeners is sent to a large settling pond to recover any values in froth that may not have settled out.

The average grade of the feed to the mill is 3% copper. About 25% of the feed is removed in the upper part of the mill in the form of concentrates by water concentration, 11.50% is recovered as concentrates from the flotation machines. The average tailings (slimes and sands) run 0.15% copper. This, after allowing for loss in overflows and leakages, gives a net recovery in the form of concentrates of 96% of the copper in the original ore. The tailings from the flotation machines have been found to be quite suitable for the manufacture of building brick, and a plant with a capacity of 17,000 bricks daily is now operating on this material.

The equipment for each of the 7 sections of the concentrator is:

1 12x24-in. Blake crusher
2 8x20-in. Blake crushers
6 coarse-concentrate Harz jigs
6 ⅜-in. concentrate Evans jigs
12 fine-concentrate Evans jigs
4 sets of 55x24-in. rolls
18 Wilfley tables using Butchart system of riffling
8 8-ft. Anaconda classifiers
6 7½x72-in. Hardinge mills with individual 225-hp. motors and using steel lining and steel balls
6 Dorr Simplex classifiers in closed circuit with Hardinge mills
4 Minerals Separation flotation machines, having 15 agitators and 14 spitzkasten each, and individual 150-hp. motors
The necessary elevators, trommels and dewatering tanks

Section No. 1 has 4 fine-concentrate Hancock jigs instead of Evans jigs and uses 8x12-ft. tube mills instead of Hardinge mills. The remainder of the equipment is practically the same.

The product of water concentration is drained in suitable tanks and then transferred in cars to the smelteries. The concentrates from the Minerals Separation machines are thickened in Dorr thickeners 50 ft. in diameter and 12 ft. in depth, and the thickened material is filtered in Oliver filters, whence it is conveyed on belts to the roasting plant. The tailings are sluiced away.

*Excerpt from a paper presented to the Canadian Mining Institute by E. P. Mathewson, manager reduction works, Anaconda Copper Mining Co., Butte, Mont.

Some Notes on Flotation

By R. C. Canby*

SYNOPSIS—Some personal reminiscences of the early days of flotation practice. Experiments on Teziutlan ores and introduction at Miami. Confusion of physical and mechanical factors influencing practice. Flotation is believed to be more broadly applicable than any other process.

About four years ago I was called upon to consider the relative advantages of utilizing a magnetic plant that was available for removal to Teziutlan, as an alternative to flotation. A shipment of some of the ore had been sent to England for test by the Elmore vacuum process and later, at my suggestion, part of a shipment was diverted to Minerals Separation for trial by the agitation froth method. The extraction of the ore by the two processes was almost identical.

At that time flotation had made little progress in the treatment of copper ore, but a great change has taken place since that time. Then experienced metallurgists would ask, "Do you mean to tell me that if there was anything in flotation, all of our big copper companies would not use it?" That was the prevailing attitude, but the successful introduction of the process at the Miami has had great influence in bringing to pass its present widespread application. It is of interest to note that the experiments leading to the introduction of flotation at Miami were due to a casual reference I made to the Teziutlan experiment.

Even now, in spite of the great number of plants in use, the metallurgist finds it impossible to point to any thoroughly established practice or to indicate any improvement that had not been largely empirical rather than the result of development from operating experience.

Experiments on Inspiration Ores

Somewhat later than the Teziutlan experiment Minerals Separation performed a series of tests on Inspiration ores, utilizing the existing crushing machinery of the original test plant that had been used to develop the gravity flow sheets for the proposed mill. In the original test the arrangement of the plant was such that the ore pulp flowed directly from the small Hardinge mill to the agitation froth type of flotation machine without any intermediate gravity or table concentration. This arrangement led to an important error of deduction. This was to the effect that while the flotation process was perfectly suited to the silicified schist, it was not applicable to the kaolinized granite ore, but that if this kaolinized granite was thoroughly mixed with silicified schist, up to about 10% of the total weight, just as good flotation results were obtainable as though none of the kaolinized granite were present. Consideration of the conditions under which the test was made lead to a purely mechanical explanation of the difficulty. It is that in the grinding of the much softer gangue of kaolinized granite in the Hardinge mill the ore was so readily pulverized that there was not sufficient attrition to grind properly all of the chalcocite, and that the tailings loss, upon this ore, was due to such particles of insufficiently pulverized chalcocite. From such mechanical explanation it is apparent that there need be no fear of any such difficulty at the Miami mill, since the tables would remove all such chalcocite particles before flotation was reached. Subsequent practice has confirmed this view.

Another confusion of mechanical and other causes of failure happened in the agitation froth experiments at the Miami mill. A Dorr thickener 4 ft. deep had been in use, and it was decided to increase its depth 8 ft. in order to clear the overflow. Upon making this change the tailings assays, which had previously been satisfactory, were most disappointing. By an unfortunate coincidence a change of oil was necessitated at the same time, which led to the suggestion that the trouble might be due to the new oil. It was the increased depth of the new Dorr thickener, however, which had made the difference, working a most decided change in the character of the feed. While the weight of feed increased only about 15%, the surface area, or number of particles, had increased enormously. As I expressed it at that time, I could readily imagine passing 80 to 100 tons of finely granulated lead through the frothing machine, but I could not conceive of passing the same weight of feathers. By suitably reducing the tonnage to correspond with the changed condition of feed, satisfactory results were forthcoming. In this case the explanation was mechanical, but there are other conditions, both in the composition of the ore and in the condition of the surfaces of the sulphide, that will greatly affect flotation results. And it is also known that oils or frothing agents that are supposed to be the same in composition will vary greatly.

General Uniformity of Mineral Characteristics

At the time of the question as to the applicability of flotation to the kaolinized granite, I expressed a belief that if chalcocite would float at all, it would float in kaolinized granite or in any other ore. Broadly speaking, this is correct of chalcocite as of other sulphides. Individuals of the different mineral groups are broadly consistent, and the physical qualities that cause flotation, whatever these may be found to be, will be as characteristic of the individual minerals as of their specific gravity, provided that perfectly clean mineral surfaces are subjected to the action. For this reason I believe flotation is just as broadly applicable as is gravity concentration.

In spite of the broad applicability of flotation, however, it is not a universal panacea. There is still the uncontrolled loss of oxidized copper minerals in flotation tailings. Counter-current lixiviation will obtain an almost complete extraction of this material, but requires a plant of impossible extent and lacks suitable methods of precipitation. In this connection the idea occurred to me of dissolving and precipitating in the flotation cell. Others have already had this idea, and it is probable that as soon as a general demand for its application is made, a feasible process will be worked out.

Metallurgists are, as a rule, conservative, so that it was perhaps to have been expected that they should assume an attitude of mistrust of so novel a proposition, particularly a process with which the contending proprietory process companies appeared to be so largely occu-

*Consulting Metallurgist, Wallingford, Conn.

pied with legal controversies over their respective patent rights. Then, the approach of supposedly proprietory companies toward possible users was un-American. Protective patents were alluded to, but no information as to the nature of the proposed processes vouchsafed. In addition this new process was not presented as an adjunct to prevailing methods, but existing facts were to be wholly scrapped. It is possibly natural that parties promoting proprietory processes, based on tonnage royalty, should take such a view of their property, but flotation should be more largely looked upon as an adjunct to gravity concentration, especially in its consideration for adoption in operating plants. It is the exception when one would not be justified in installing one or two actual units in connection with operating plants, and flotation results, even at their poorest, would perhaps be better than any form of gravity separation upon a product which in reason should go to flotation.

Many a metallurgist makes the mistake of concluding that the process is not applicable to his ores after only superficial tests. Sulphide surfaces are so delicate that even the merest drying of wet surfaces may have an effect that is sufficient to prevent successful flotation. For this reason samples sent away to a testing laboratory may give negative results, whereas had the pulp been treated as it was produced it might have given good extractions. In fact, one of the most successful and largest of the present operating plants would never have been built had the management depended entirely upon the results from samples sent away for test.

Agitation-Froth and Bubble-Column Types

As to what would be the determining point in deciding between the agitation-froth type and the bubble column type it is hard to say. It is possible that there are instances in which the agitation froth machine is the more efficient. Some writers say it gives higher extraction, but in the Miami district this is apparently not the case. The agitation froth machine is usually operated in series, giving anywhere from 8 to 16 re-treatments. In the other process but one treatment is usually given and the cells are generally in parallel, with some important exceptions, however. The bubble column gives, perhaps, a higher grade of concentrate and is used in numerous instances for the re-treatment of agitation froth machine products. As to the amount of attention necessary to operate, this is in either type largely a matter of frothing agents. Some oils require almost constant attention upon the part of the operator, while in other cases not so much is required. With good normal working conditions, one man can handle more flotation machines than he can of any form of gravity machines for an equal tonnage, and there is no considerable advantage of one type over another so far as this particular point is concerned. As to the relative power, one of the largest experimenters finds that the power consumption is about equal, but at the Miami the power was found decidedly in favor of the bubble column. Power consumption increases greatly with pressure. The pressure for a given volume varies also with the freedom or otherwise with which the air passes through the porous medium. There is room here for experimentation to reduce the pressure to the minimum.

Coming to the question of the oil, or the frothing agent, it is almost impossible to say anything without venturing into the basic reasons for flotation. The question of the oil and the underlying principles are closely associated, and as yet we cannot fully answer the question as to what the unvarying qualities of an oil are so that they can be determined, except experimentally, nor can we give absolutely the definite explanation of flotation causes. The claim has been made that all the flotation processes are of exactly the same nature and based upon the phenomena of surface tension. Careful experimentation seems to bear this out.

The Use of Oils and Acids

The question of the selective affinity of oils for sulphide surfaces is confusing, but this confusion becomes less or is overcome when we look at the subject from the point of view of adsorption. This branch of the chemistry of colloids seems to simplify the matter and to offer an opportunity for the experimental demonstration of all the features of flotation. But even with this, it is still a considerable step to the practical predetermination of absolute essentials in the modifying agents. If we are to find all our embracing theory in adsorption, it would seem not to demand the two characters of oil, for frothing and collecting. Nor in practice does the evanescence of the bubble-column froth seem to suggest this necessity as possibly might the requirements of the separating spitzkasten of the agitation froth machine.

At Teziutlan I found that acid was necessary to cause the zinc to float. I found, however, that the actual presence of acid during flotation was not necessary, but that if the ore was given an acid treatment and then washed thoroughly upon a filter until no trace of the acid was discernible, the same result was obtained as though the acid had not been washed off. In such a case it is difficult to believe that it is the effect upon the emulsification of the oil that gives its effectiveness to the acid. An extremely small trace of acid might have the effect of preventing emulsification. I visited a plant recently in California where a distinctly acid froth appeared necessary, the acid consumption being almost prohibitively high. The possibility of a preliminary acid treatment and circulation of the acid solution was discussed both as a matter of economy in acid and its effect on porous-bottom blankets. If one assumes that there is insufficient coating oil present, it is conceivable that the prevention of emulsification of the oil might have effect. But the question of oil quantity is too broad to discuss in a single paper. It is noticeable, however, that in none of the various explanations that have been offered recently as to the causes of flotation, does any single theory, so far as I have seen, indicate that there are any experimental data tending to controvert the statement that all forms of flotation are dependent upon surface-tension principles.

Hydrated Lime in Concrete

In a recent paper before the Engineers' Club of St. Louis, H. E. Wiedemann gave the following as his conclusions regarding the use of hydrated lime in concrete. The use of small amounts (8% on a 1:2:4 mix up to 16% on a 1:3:5 mix) will:

1. Render the concrete highly plastic and homogeneous, producing density and uniformity in the finished product.
2. Add to the life and efficiency of a concrete pavement or floor, on account of the uniform resistance to wear and internal stress, produced by its use.
3. Render concrete waterproof by filling the voids in the fine and coarse aggregate. These functions are of the greatest importance and warrant the use of hydrated lime.

Froths Formed by Flotation Oils

By William A. Mueller*

SYNOPSIS—The froth character of the oils used in flotation is constant with each oil, but differs with change of oil. Pine oil is most widely used and has typical qualities, as has each of the other oils described.

Before attempting to do flotation work, it is essential that one should know something about the nature and character of the froths produced by the various oils used. In this discussion it is my intention to give an outline of results that accompany the use of the most common oils.

For experimenting with various oils for flotation small flotation machines of various makes are used. For studying the various froth characteristics of an oil one of these machines works pretty well and is handy to use. The froth produced by various oils differs with the machine in which it is made. For instance, in the Minerals Separation type of machine, where the froth rides in the spitzkasten for some time before leaving it, there is plenty of time to collect and mat together, and in this case the froth always lies in a "dead" state, only coming off as it is forced out by other froth from the rear. In this case the froth loses its characteristics so far as the bubble itself is concerned.

In the Callow type of machine the froth is always in rapid motion and no dead froth accumulates. It is kept overflowing by the constantly rising bubble column formed. In the Cole-Bergmann and Flynn-Towne types of machines the froth acts as in the Callow type. In these two, however, a deeper froth column is carried and this makes a slight difference in the froth, making the bubbles slightly smaller. In the Hebbard type of Minerals Separation machine the froth is in more rapid motion than in the regular machine, owing to there being no settling compartment and also owing to the introduction of air. Here again there is no accumulation of dead froth except at times around the shaft of the agitators.

In adding oils for flotation it is of the utmost importance that they be well mixed with the pulp before flotation is attempted. This is usually done by adding the oils in the mills during grinding, and this is the most desirable method. Sometimes where this cannot be done, as is the case where primary slimes are treated by flotation and the oils are not wanted in the rest of the feed, a Pachuca tank is used for the mixing. This works fairly well, although it is not the most desirable way of mixing where the entire pulp is to be treated. If not thoroughly mixed, the oils kill froth rather than produce any. When a machine is in good working order and some raw oil suddenly gets into the pulp, the froth immediately seems to dissolve, leaving the pulp showing through the froth. In these cases the froth rushes back and forth in the machine, the bubbles become very brittle and finally disappear.

Raw oil must not, however, be confused with a high water-level. Sometimes a machine is operated with a high water-level; that is, the froth will be very shallow, sometimes only several inches in depth. In this case the pulp will show up through the froth and give much the same appearance as raw oil. This condition can easily be distinguished from the raw-oil condition by noticing the height of the pulp level. The practice of using a shallow froth is considered good by some metallurgists, but does not really aid except where there may be a temporary air shortage in the air type of machine. The usual depth of froth in the Callow type of machine is about 15 in.; in the Cole-Bergmann and Flynn-Towne machines it is from 24 to 36 in., while in the Minerals Separation type the froth level varies from 6 to 12 in. in the spitzkasten, and in the Hebbard type it runs from 6 to 10 in. The raw-oil condition in a machine can readily be distinguished from the high level of pulp condition by the depth of pulp from the top of the machine at the time the condition is noticed. The raw-oil action is detrimental to flotation and should be avoided. Cup greases and lubricating oils give the most trouble of this kind in plants, as it is very easy for a lump of grease or some oil dropping from bearings to find its way into the flotation-feed launder. Wherever detected these faults should be immediately remedied. Greases and lubricating oils are not the best of flotation oils, and their action will be discussed in a later paragraph.

FROTH FROM COAL-TAR CREOSOTE

Another important feature in adding the flotation oils is that they be fed in some continuous way and not spasmodically, since the latter would entail constant attention at the machine and abnormal conditions at all times. There are several devices for uniform oil addition. One is by a pump in which the stroke of the piston can be varied, thus giving any desired amount of oil, from a drop at a time to a steady stream. Another satisfactory device is a method whereby the oil is taken from the rim of a wheel which operates so that the rim passes through oil contained in a reservoir. A piece of flat metal is then fixed by a setscrew and spring to rest against the rim. By adjustment of the screw the piece of metal can be shifted across the rim so as to take in a greater or less area, thereby increasing or diminishing the oil flow. Still a third method consists of a small bucket or two on an endless chain passing over a pulley, much the same as a bucket pump, located above the launder where the oils are to be added and another pulley in a barrel or drum containing the oil mixture below. The bucket carries

*Magma Copper Co., Superior, Ariz.

its small amount of oil up, discharges into the launder and is refilled again on passing through the barrel, etc.

In making any changes in increasing or decreasing the amount of oil or adding different kinds of oil, make them very gradually. In increasing or diminishing especially, be careful and only change the rate very slowly, allowing enough time to give the change a chance to show up in the machine. Especially is this important when the oils are added in the mills, as it takes some time for a change in oil to make its appearance, since it is diluted to such an extent and worked over such a comparatively large volume.

The froth characteristics here described apply to live froths such as are formed in the air types of machines. The agitator type, with the exception of the agitator-and-air type combined, usually has a spitzkasten or settling compartment in which the froth congeals and so loses its bubble characteristics. In these machines the froth characteristics are not so noticeable.

Characteristics of Pine Oil

Perhaps the most common oil used in flotation work is pine oil. There are several grades on the market, but as the various kinds have practically the same effects on the kinds of froth, I will treat this oil in a general way.

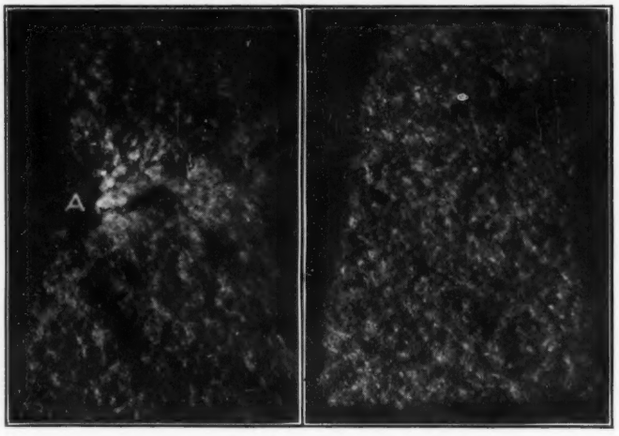
Pine oil is rather soluble, and it is this characteristic that is largely in its favor, as its presence, once used, is always detected in the mill water as long as the tailings and concentrates are dewatered and the water reused. After using pine oil a short time, only a little of it need be added—just enough to make up for any small amount that may have been lost or carried away by the concentrates after dewatering.

The pine-oil froth is brittle and the bubble produced is small, the largest one being only about ¼ in. in diameter. A small amount of oil produces a large quantity of fine-grained froth. The bubble film is very delicate and, on rising to the surface, breaks immediately. Its burden of mineral, if there is any, is deposited on the bubble immediately following, and thus the mineral is carried along on the surface until it flows over a lip or otherwise is removed. Pine oil as a general rule is a rather poor mineral collector, but a good frothing agent. For this reason it is generally used only as a frother, although there are some cases where it will take the place of a mineral collector as well as the frothing agent. Its action is delicate, and at plants where pine oil is largely used, the machines will require much closer attention. For instance, it is a good mineral collector on ores carrying chalcocite and on some zinc ores. A pine-oil froth, in addition to being brittle, is also watery and at times, when there is too much of it present, it tends to make a dirty froth and low-grade concentrate. When present in these large amounts, the concentrate froth will often carry large particles of silica and gangue material; that is, some that will pass 28-mesh and stay on a 60-mesh screen. The froth, however, does not toughen up because of its excess oiling, and in this way pine oil differs from most others. The froth will be dirty, as is the case with other oils, and cannot be cleaned, but the latter is due largely to excess froth rather than to the toughness of the froth as is the case with other oils. By the addition of acid, or sometimes a caustic, its action as a mineral collector can often be increased, but it still retains the same characteristics of brittleness and delicacy.

Next to pine oil perhaps the most important flotation agent is coal tar. As a general rule the coal tars are too stiff and thick to be used by themselves and so must often be diluted with some other oil, preferably one in its own class. The oils commonly used for this purpose are coal-tar creosote, cresol and other coal-tar products. Sometimes, however, wood creosote, fuel oil or others are used.

The action of coal tar varies somewhat with the coal and the heat treatment by which it is produced. For these reasons all coal tars are not suitable for flotation. I published some experiments along these lines in the *Journal* of Oct. 9, 1915. As a rule the froth produced from a coal tar suitable for flotation is uniform. The bubbles are somewhat larger than the pine-oil bubble, ranging from ¼ in. to several inches in diameter and sometimes, when the tar contains a large amount of creosote, the bubbles are even larger than this, reaching as much as 6 to 8 in. diameter.

Coal tar is a poor frothing agent, but a good mineral collector, and it is seldom used without mixing with some pine oil or other frothing agent. The bubble from coal tar itself is also brittle, but in the presence of min-



EFFECT OF FOREIGN OIL ON FROTH

ANOTHER EXAMPLE OF CREOSOTE FROTH

eral it often seems to become tougher, the mineral and oil film apparently mating together. The froth from this oil is always mineralized to a high degree when it is mineralized at all. Coal tar, with a suitable frothing agent, is adapted to almost any ore. By this statement I mean that it is not adapted to any one mineral, but works as a rule with the minerals of copper, zinc and some others. The froth does not acquire any great depth unless some other oil is mixed with it. For this reason we seldom see a straight coal-tar froth except in an experimental machine. Coal tar is hard to mix with the pulp, and it cannot be done well except by grinding. I have seen coal tar, even when mixed with pine oil, separate when reaching the machine, although in this case it had been added in a Pachuca tank at the head of the machine. When coal tar shows up in the machine as raw oil, it hasn't the strong froth-killing power of the other oils, but lies on the froth in flakes, sometimes deadening the froth in the immediate vicinity and at other times seeming to mate the small bubbles together, forming a sort of hole in the froth, toward which the bubbles in the vicinity have a strong tendency to rush. Arriving, they seem to be swallowed up much as a cork will act when thrown into a whirlpool. Raw coal tar in the machine is not so detri-

mental as the other oils, but nevertheless it should be avoided. When in great excess, coal tar has a strong tendency to separate, as has been noted, even when apparently well mixed. Even though it has no strong frothing power, when too much is used it will cause some excess frothing and a dirty froth, though not so easily as other oils.

Coal-Tar Creosote

Coal-tar creosote is used mostly as a dilutant for the cheaper coal-tar oil, and for this purpose it is very good. The creosote bubble has a tendency to be rather large, ranging in size from about an inch in diameter to as much at 12 in. and sometimes even more. The bubble has a tendency to be tenacious. It is very tough and in breaking, the bubbles tend to expand rather than be destroyed altogether. With two bubbles side by side, the breaking seems to take place in the film uniting them, so that where there were two bubbles at first, there is only one after bursting. This enlarging of the bubble, of course, has its limit, and we seldom see them much over 12 in. diameter unless there is a great excess of creosote, when they may get to be of such size as to reach across the machine. On bursting, the mineral burden is drawn by the film to the film of the neighboring bubbles with which they were in contact before bursting. The bubble has good carrying capacity for mineral. When too much oil is present, however, there is the same tendency to carry gangue, and this is usually at the expense of the mineral. The oil mixes rather easily, the action in the Pachuca tank being sufficient, although mixing in the grinding mills is at all times to be recommended.

Wood-Creosote Bubbles

Wood creosote has some of the same characteristics of the coal-tar creosote, but differs widely in others. The toughness of its bubble is even more marked. The size of the bubble is also somewhat different. The two oils are not interchangeable—that is, the one cannot be used as a substitute for the other, as coal-tar creosote seems to work better on copper-bearing ores than the wood creosote and the latter seems to work better on zinc ores. Wood creosote is often used as dilutant for coal tar in the flotation of zinc ores. The size of the bubbles varies greatly. The characteristic froth shows small ones resembling the pine-oil bubble, together with the larger ones. There will be a large one about 3 in. diameter as a maximum; then there will be a group of smaller ones, ranging in size up to maybe ½ in. diameter, which separate the larger ones from each other. This is the characteristic wood-creosote froth. The froth, like that of coal-tar creosote, is tough, and a small excess of oil makes a dirty and voluminous froth that is hard to break up. The bubble varies from this type when an excess of oil is used, tending to become larger and more elastic.

Turpentine is not used so much at the present time as when flotation first appeared in this country. The turpentine froth is persistent and elastic. It has a tendency to hold everything that comes in contact with it, and for this reason it was formerly used to bring up the middlings and was added after the concentrates were taken off. For this purpose it was good, but the froth is so tough that it is hard to break down, so that cleaning it is difficult. Usually the middling produced by means of the turpentine could not be cleaned to any appreciable extent. The turpentine bubble ranges in size from ½ in. to 2 or 3 in. diameter. It is elastic, and the volume of froth produced is always excessive and, as a rule, low-grade. For this reason it is not used much at present.

Cresol, or Cresylic Acid

Cresol, or cresylic acid, formerly was the chief flotation agent used in the flotation of copper minerals, but its use is now limited to small proportions in the mixtures with coal tar. The cresol bubble is of medium size—that is, from ½ to 2 and 3 in. diameter—and as a rule the bubble is not too brittle and not too tough, but made a good froth to handle. The nature of the oil, however, made it disagreeable to handle and also somewhat dangerous; this, together with the bringing out of coal tar and the advance in price of cresol, gradually brought it to a point where only a comparatively small amount is now used.

The oil was a good frothing agent as well as a good mineral collector, and its use was almost universal a short time ago. The froth is rather easy to break down, and for this reason the concentrate produced is rather easily cleaned. The oil is very slightly soluble in water and mixes rather easily. Violent agitation, as in a Pachuca tank or in the Minerals Separation type of machine, is often enough to give good distribution and a good flotation froth.

The froth produced by fuel oil is of the same appearance as that of coal-tar creosote as far as the bubbles are concerned, which are nearly the same size, ranging from 2 in. to 4 and 6 in. diameter. The froth, however, is very brittle when the right amount of oil is used and is much cleaner than the creosote. In fact, the froth is almost too clean, so that a clean tailing is hard to make with fuel oil alone. Mixed with some oil like creosote, however, it sometimes does good work. The concentrates from the preliminary treatment often need no further treatment. Where a final product is made as concentrate the tailings are usually re-treated, and in these cases the creosote effects seem to carry through to the other treatment, while the fuel oil often has to be added in the second treatment. Various ores differ slightly on this point. Again, a little fuel oil in a coal tar-creosote mixture will sometimes aid in cleaning the froth.

When fuel oil is in excess, the froth produced is stringy and the bubbles often get to be of such size as to stretch across the machine. I have seen them over 2 ft. in length. The froth under these conditions is also dirty and will pass through a cleaner with practically no better grade being produced than before entering. Acid is sometimes an aid in the use of fuel oil, especially when the oil is in excess. The froth from excess fuel oil is hard to break down.

Pine-tar oil is coming into the lime-light more just now as a possible flotation agent for copper carbonates, but I doubt whether it will be useful alone. It is stiff and flows poorly, so that it must be mixed with some other oils in order to make it of such viscosity as to flow so that it may be added steadily and slowly.

The froth resembles that from wood creosote and pine oil in appearance of the bubbles, but in texture it is very much more fine-grained than the wood creosote. It is a powerful frothing agent similar to pine oil. It is easy to flood the plant with froth from this oil. The froth is characterized by being dirty, but, like pine oil, is capa-

ble of holding up considerable coarse mineral as well as gangue. When a flood of this froth reaches the cleaner, it is subjected to very little cleaning owing to its frothing character. Often the addition of a small amount of fuel oil will tend to make a cleaner froth, but with the pine-tar oil a very clean froth must not be expected except at the cost of high tailings.

Oleic acid is used at several plants in this country and is confined mostly to zinc ores. It produces large bubbles and a tough froth. The size of the bubbles varies with the amount of oil used, but ranging from several inches to a foot in diameter. The froth is very persistent and stringy, and the bubble film is often strong enough to support light objects.

Eucalyptus oil is used mostly in Australia, although a small amount of it may be encountered in this country at times. Its cost, however, is very much against it here.

Introduction of Foreign Oils

Under this head I will also discuss the effects of greases, as they really come under the same heading, even though they are not literally oils. As mentioned in the beginning of this article, under no circumstances should these oils or greases be permitted to come into the feed delivered to the flotation machines. The sources are numerous, and I will not go into them in detail, but a mention of several of the more common ones will probably not be amiss. A common place to find some of this trouble is around the bearings and gears of the pebble and ball mills; here an enormous lot of grease and oil is used and a great deal wasted. Dripping bearings give their share of trouble. How often do you think, when you have a hot bearing and pour water on it, that you may be giving your flotation department trouble? If foreign oils get into the feed before entering the mills, it is then mixed and its effect is distributed over a large amount and does not give quite the trouble as when it finds its way in after leaving the mills. Sometimes acid will remedy the effect of foreign oils when they cannot be avoided in any other way, if their source is ahead of the grinding mills, but the effect of the acid on the flotation must also be considered. Acid in some cases is as deterimental to the flotation as the oil itself would be; in this case the only thing to do is to find the source of oil and eliminate it. Froth from lubricating oils is tough and stringy and carries little mineral value and is almost uncleanable. The bubbles are hard to break down and, when once broken down, will form again at the slightest opportunity. A large amount of foreign oils come from cleaning up around the plant. The mineral content of tailings is not reduced by the action of these oils; they merely act as an annoying frothing agent that may bury the plant in froth.

The Use of Oil Mixtures

Most plants are working on mixtures of various oils and do not depend on any one. These mixtures vary with the ores to be treated and the conditions around the plant. In experimenting with the various oils we can readily see which are doing the best work; also, we can tell after a little while what the various oils may need as an aid to make them do better work. There are several things that determine this, as for instance, suppose we are trying a coal tar with a certain ore and we should get a rather brittle froth and at the same time one of a high grade. The froth would probably be shallow, and in this case it is evident that we should need a frothing agent of some kind and should probably add a small amount of pine oil. After adding this we should still get a rather brittle and watery froth, as both pine oil and coal tar will produce such a froth. Probably we should let this go if it was capable of giving the right results. Suppose, however, that it was a tougher froth that we were after, then we should look for an oil that was capable of producing the kind of froth that we wanted and we should, in all probability, select coal-tar creosote. Varying proportions of this oil would give us a froth that would have the desired characteristics. All oils and mixtures must be determined on the ground, and there is no better way than in the large plant. Small testing machines are procurable, but even these sometimes lead us on the wrong track in oil selections. On the other hand, these machines are often reliable in a way, as for instance, in testing for the amounts of oil to be used. To select an oil for the large plant from a test on one of these small machines is often poor policy. Mixtures are determined by other factors as well. One of these, and an important one, is a mixture that will be liquid enough at any time during varying temperatures. Some plants to get around this have what they call a "warm-weather mixture" and a "cold-weather mixture." The two mixtures have each varying proportions of the oils constituting it, as, for instance, the warm-weather mixture may be something like this—coal-tar 80% or more and creosote 20% or less. The cold-weather mixture may go as low as 40% coal tar and the other 60% creosote, cresol or other oil in order that it will be liquid at that certain temperature. The viscosity of coal tar makes these mixtures a necessity at times. Other plants sometimes heat their mixtures either by steam pipes, electrically or by blowing compressed air through the tank holding them. The last can only be done where the mixing tank is near the compressor so as to receive warm air.

Persistency of Pine Oils

A coal-tar mixture usually contains at least 75% coal tar when it can be kept liquid at that point, although some tars will exceed this figure while others will not use quite as much. There is not so much difference in the appearance of the froth produced by the mixture containing 80% coal tar and the one produced by one containing 50%, provided, of course, the same oils are used in the dilution of the coal tar.

Many operators get an oil that will work well with their ore and are then satisfied, but this is the wrong idea. It does not take much to experiment a little on the large plant, and one can easily tell after a little while whether he is doing good or not before any serious trouble results, and in this way valuable information can often be gained that well repays the effort made.

Where pine oil is used in the mixture and the water from the dewatered products returned to the mill, this oil can easily be cut down to practically nothing after a short time. While pine oil is considered expensive, the amount used after the first month or so is so small that its cost per ton of ore milled can almost be neglected. I know of one plant that is operating on pine oil as its main flotation oil and the consumption per ton of dry ore milled is only 0.13 lb., and tailings of 0.17% copper are produced. At another plant, operating with a mixture con-

taining pine oil, the oil consumption the first few months ran about 1½ lb. per ton of ore. After the first few months this consumption was cut to ¾ lb. per ton of ore. This drop was due to the dissolved oil in the returned water. In mixtures the pine oil can be cut to less than this, and in some plants it is omitted altogether, the amount in the returned being sufficient. Occasionally a little is added from time to time, and then again a little is added separately by just a drop or so every few minutes to make up for any loss and extreme dilution, so that the amount used is a negligible quantity and its cost is also minute.

Where the heavier oils are used that are less soluble it seems to make no difference whether the water is returned or not. This is accounted for by the fact that these oils exert a selective action with the mineral—have a tendency to stick with the mineral when it goes off in the froth. For this reason there is practically none of this oil that is returned except that which is soluble in the water, and with the heavier oils this is a negligible quantity. The returning of the water also has its disadvantages because where there is much oil in the returned water, an inexperienced operator is often deceived by the appearance of the machine. The froth may be of good appearance, and yet the machine will not be doing its best work, because the returned water may contain such quantities of oil that on addition of the regular flotation mixture, the froth is excessive. The natural thing to do is to cut off the oil mixture. This done, the machine will again produce the froth characteristic of the pine oil or other soluble oils present which are not good mineral collectors, and consequently the benefits of the machine are sure to lessen owing to loss of mineral. In these cases the returned water is a bad rather than a good thing. This factor is a cause of the falling off in flotation recoveries and other troubles in many plants today. Where this trouble exists, it should be remedied by dilution of the returned water with fresh and a decreasing of the frothing agent in the mixture used. Sometimes it may be best to discontinue the use of any frothing agent until the returned water is of such dilution as to warrant further addition of this type of oil.

As a general rule the best froth to be used is one in which the bubbles are of a medium size and rather tough, although too tough a bubble should be avoided. For chalcocite, pine oil works best, but this froth is delicate and a froth of this kind needs constant attention, so that an operator is not able to care for as many machines under circumstances of this kind. Coal-tar mixtures of from 50 to 80% coal tar and 50 to 20% creosote, with small amounts of pine oil added from time to time, will often give the same results and much steadier conditions than the pine oil on chalcocite ores. The best mixture would have to be worked out in the plant.

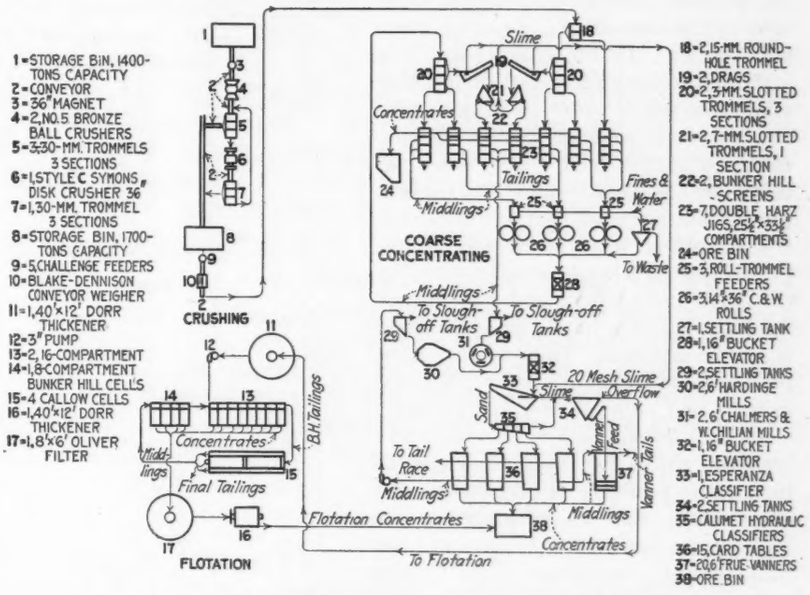
Chalcopyrite responds readily to the same mixtures as chalcocite, but the pine-oil froth does not do very well with the chalcopyrite. Zinc and lead ores vary greatly. Some will respond beautifully to mixtures of coal tar and wood creosote and some with coal-tar creosote, while others will not respond with any oils but mixtures of wood-distillation products. Then there are still others that seem to require the addition of acid in order to do anything at all.

Bunker Hill and Sullivan Milling Data

By R. S. Handy*

The Bunker Hill & Sullivan Mining and Concentrating Co. has concentration equipment with a maximum capacity of 585,000 tons per year. The total horsepower required is 1,500. Bronze ball crushers, No. 5, and Symons disk crushers are used as preliminary breakers. The ratio of concentration is 7½:1. The total mill water used is 4,500 gal. per min., and 45 men are required for the mill operation.

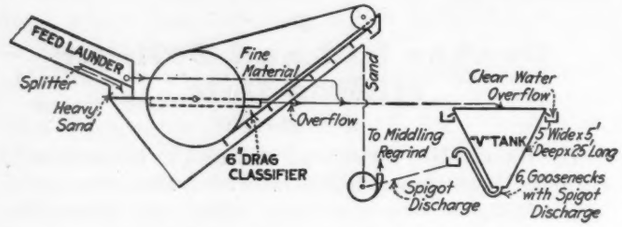
The mill heads assay 9% lead and 3.5 oz. silver, while the tailings run 1.4% lead and 0.9 oz. silver. The percentage of extraction, therefore, is 84% lead and 78% silver. The accompanying flow sheet shows the scheme of operation at the mill. The system is about as it has been in recent years, and since the adoption of flotation no radical changes have been made. The overflows from the slime-settling tanks have been arranged so that they are now all perfectly clear and are being used for wash water in the mill. The floor washes, dirty overflows from the grinding-mill feed boxes, overflows from the roll feeder tanks, etc., which have been more or less of a problem for years, are now satisfactorily taken care of by the slough-off system, as shown in the accompanying drawing. The overflow from these tanks is now also clear, effecting a material saving over the old system of floor tanks, which were used for this purpose. There is now no mineral-carrying pulp leaving the mill except that which flows through the automatic sampling devices, so that there is no danger of loss of anything of value.



FLOW SHEET OF BUNKER HILL & SULLIVAN MILL

*Mill superintendent, Bunker Hill & Sullivan mill, Kellogg, Idaho.

The present arrangement of flotation equipment is shown in the flow sheet. The vanners are now run to produce a concentrate above 60% lead; tailings are correspondingly higher than they formerly were and are pumped to the flotation thickener, where they are joined



BUNKER HILL SLOUGHING-OFF SYSTEM

by the dirty portion of the slime-thickener overflows to provide feed for the flotation plant. The details of the Bunker Hill flotation cell are shown in the accompanying drawing. The pumps are a specially made Gould type, with white-iron liners, wearing plate and runner. In the stuffing-box is a cast-iron bushing of special design that allows the use of water packing to protect the shaft without unduly diluting the pulp in the cells. The water for this purpose comes from the concentrate thickener and contains considerable oil, which is an advantage. Compressed air is blown directly into the suction of these pumps under a constant head so that this important regulation is easy to maintain. The present pumps have been in constant service for seven months and show little signs of wear.

In the development of flotation our constant object has been to secure as high-grade products as possible for the same reason that we have striven for high-grade products throughout the mill—namely, to obviate high freight and treatment charges. The sloping discharge for the froth of the Bunker Hill cell and the natural tendencies of the treatment itself have enabled us to get from these cells a froth assaying between 50 and 55% lead. The Bunker Hill cleaner cells give a product running between 62 and 65% lead. The Callow roughing system consists of standard equipment with the exception that the pneumatic frame in the bottom is made up of eight sections, and around each section a groove is cut so that the cloth cover may be secured by driving rope over the cloth into this groove in the same way that filter bottoms in cyanide tanks are secured.

ECONOMIC MILLING DATA

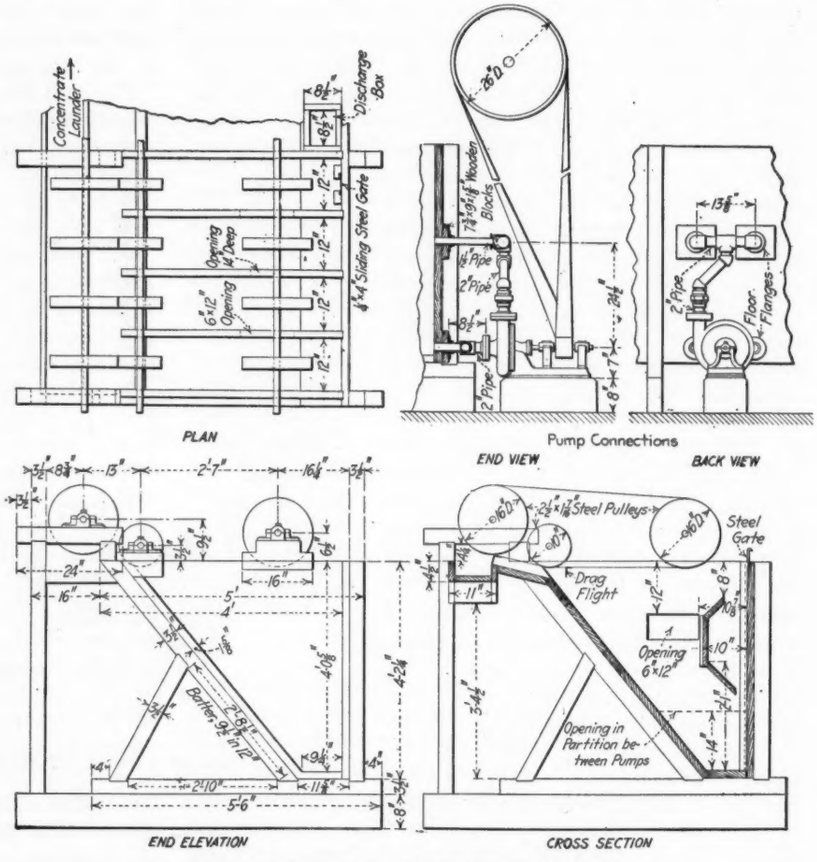
Day's run	356
Tons milled	454,636
Assay feed, % lead	9.9406
Assay feed, oz. silver	3.8277
Contents feed, tons lead	45,198.72
Tons concentrates	59,901.14
Average assay concentrates, % lead	62.2565
Average assay concentrates, oz. silver	21.6738
Contents concentrates, tons lead	37,292.37
Per cent. extraction, lead	82.52
Contents feed, oz. silver	1,740,217.50
Contents, concentrates, oz. silver	1,298,284.22
Per cent. extraction, silver	74.61
Value feed	$5,144,653.74
Value concentrates	$2,384,543.28
Economic extraction, %	46.35
Tons milled per 24 hr.	1,277.06
Tons concentrates produced per 24 hr.	168.26
Tons lead produced per 24 hr.	104.75
Cost per ton milled	$0.421
Cost per ton concentrates	$3.103

COST OF SHIPPING

The company shipped 59,423 tons concentrates at the following cost:

	Per Ton		Per Ton
Labor loading	$0.182	Contingent expense	.007
Representatives at smelteries	.041	Administrative expense	.012
Supplies	.006	Repairs	.011
Assaying	.021		
Heating	.008	Total	$0.288

The grade of froth from the Callow cells is about 30% lead, the object of these machines being to produce low-grade tailings, and the froth is cleaned up in a Bunker Hill machine. The flotation equipment in each section handles from 95 to 100 tons per day of material, about 95% of which passes 200-mesh. There are 16 pumps and 32 cells in the main Bunker Hill section and four pumps and eight cells in the cleaner section. Pine oil is used in one section of the mill and eucalyptus oil in the other. The latter makes a higher-grade froth than the former, and the consumption is a little over half that of pine oil, making it a better oil to use.



THE BUNKER HILL FLOTATION MACHINE

For keeping the dilution constant at 3 to 1 we use a Troemner bullion scale, upon the sliding scale of which is laid out a curve giving the dilution due to a given weight of pulp.

The constant volume of pulp is suspended in a vessel from the top part of the scale, and when the scale is balanced, the sliding pointer reads directly in dilution.

COST OF CRUSHING AND CONVEYING

	Average per Ton for the Year		Average per Ton for the Year
Crushermen	$0.002	Crushing parts	(a)
Conveyormen	.005	General machine parts	.002
Roustabouts	.001	Oil and waste	.001
Laborers	.006	Miscellaneous	(a)
Screens	(a)	Liners	(a)
Belts	.007	Machine-shop repairs	.001
Buckets	.001	Building repairs	.002
Roll shells	.002	Mill-shop repairs	.003
Roller shells	.001	Electric power	.025
Concaves	....		
Mullers	.002	Total	$0.061

(a) Does not show in third decimal place.

COST OF SCREENING

	Average per Ton for the Year		Average per Ton for the Year
Machinemen	$0.009	Trommel screens	.006
Roustabouts	.001	Building repairs	(a)
Screens	.002	Mill-shop repairs	.003
Belts	(a)	Electric power	.004
General machine parts	(a)	Water and water power	.001
Oil and waste	(a)		
Miscellaneous	(a)		
Liners	(a)	Total	$0.026

(a) Does not show in third decimal place.

COST OF JIGGING

	Average per Ton for the Year		Average per Ton for the Year
Machinemen	$0.018	Machine-shop repairs	(a)
Oilers	.008	Building repairs	0.005
Laborers	(a)	Mill-shop repairs	.002
Roustabouts	.001	Electric power	.013
Screens	.002	Water and water power	.004
Belts	.001		
General machine parts	(a)		
Oil and waste	.001	Total	$0.055
Liners	(a)		

(a) Does not show in third decimal place.

COST OF GRINDING

	Average per Ton for the Year		Average per Ton for the Year
Machinemen	$0.018	Pebbles	.002
Roustabouts	(a)	Oil and waste	(a)
Laborers	(a)	Miscellaneous	(a)
Screens	.001	Machine-shop repairs	(a)
Belts	(a)	Mill-shop repairs	.003
Ring dies	.001	Electric power	.022
Mullers	.002		
General machine parts	.001	Total	$0.050

(a) Does not show in third decimal place.

COST OF CONCENTRATING

	Average per Ton for the Year		Average per Ton for the Year
Machinemen	$0.019	Building repairs	.002
Oilers	.008	Mill-shop repairs	.011
Roustabouts	.002	Electric power	.018
Laborers	(a)	Compressed air	.005
Belts	.002	Water and water power	.003
General machine parts	.001		
Oil and waste	(a)	Reconcentrating expense	.001
Miscellaneous	(a)		
Liners	.001		
Electrical repairs	(a)	Total	$0.076
Machine-shop repairs	.003		

(a) Does not show in third decimal place.

GENERAL MILLING EXPENSE

	Average per Ton for the Year		Average per Ton for the Year
Superintendent and foremen	$0.013	Electric light	.005
Shift bosses and sampler	.009	Heating	.014
Roustabouts	.001	Assaying	.006
Laborers	.001	Train service	.001
Watchmen	.006	Contingent expense	.007
Experimental labor	.002	Depreciation	.031
Belts	(a)	Administrative expense	.012
Oil and waste	.001	Taxes and insurance	.021
Miscellaneous	.002	Free rent	.001
Tool-shop repairs	(a)	Fire protection	.002
Electrical repairs	.003	Experimental supplies	.001
Building repairs	.007	General machine parts	(a)
Mill-shop repairs	.001	South mill	.008
Electric power	.001		
Water and water power	(a)	Total	$0.156

(a) Does not show in third decimal place.

MILL-IMPROVEMENT COST

	Average per Ton for the Year
Building repairs	$0.001
Total	$0.001

TOTAL MILL-OPERATING EXPENSE

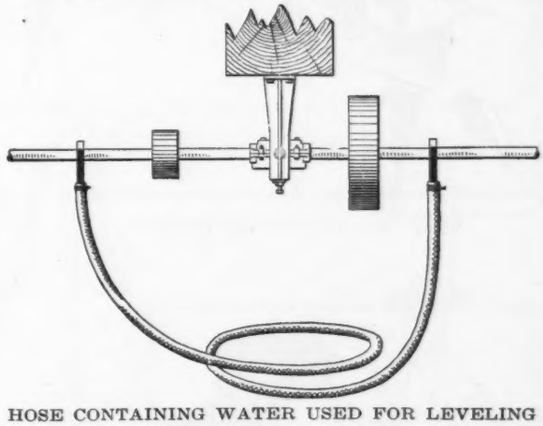
	Average per Ton for the Year		Average per Ton for the Year
Superintendent and foremen	$0.013	Electrical repairs	.004
Shift bosses and sampler	.009	Building repairs	.016
Crushermen	.002	Mill-shop repairs	.022
Conveyormen	.005	Electric power	.083
Machine men	.064	Compressed air	.002
Oilers	.015	Water and water power	.009
Roustabouts	.006	Electric light	.005
Laborers	.007	Heating	.014
Watchmen	.006	Assaying	.006
Experimental labor	.002	Train service	.001
Screens	.005	Contingent expense	.007
Belts	.010	Depreciation	.031
Buckets	.001	Administrative expense	.012
Roll shells	.002	Taxes and insurance	.021
Ring dies	.001	Free rent, light and water	.001
Roller shells	.001	Fire protection	.002
Concaves	....	Experimental supplies	.001
Mullers	.004	Mill accident (personal)	....
Crushing parts	....	South Mill expense	.009
General machine parts	.004	Reconcentrating expense	.001
Pebbles	.002		
Oil and waste	.003	Total operating expense	$0.425
Miscellaneous	.003		
Liners	.001		
Trommel screens	.005		
Tool-shop repairs	(a)		
Machine-shop repairs	.004		

(a) Does not show in third decimal place.

The valuable data in the tables given above have been taken from the report of the company for the year ended Dec. 31, 1915.

A Simple Shafting Level

To level shafting or to ascertain the relative levels of two points some distance apart which cannot conveniently be reached with a straight-edge, it is quite a common practice among millwrights, builders and others to take a common garden or other hose, insert a glass tube in

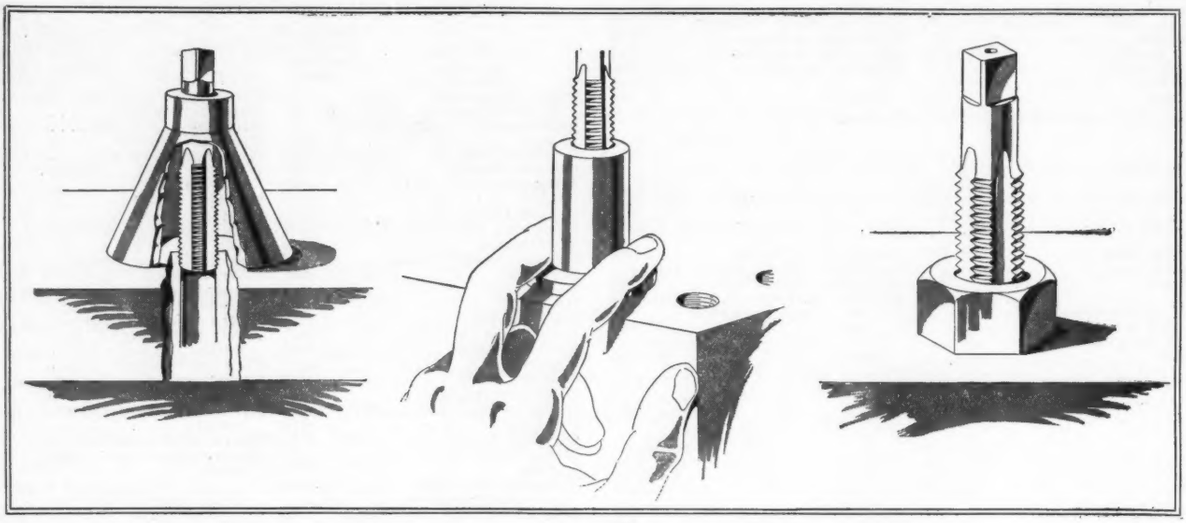


HOSE CONTAINING WATER USED FOR LEVELING

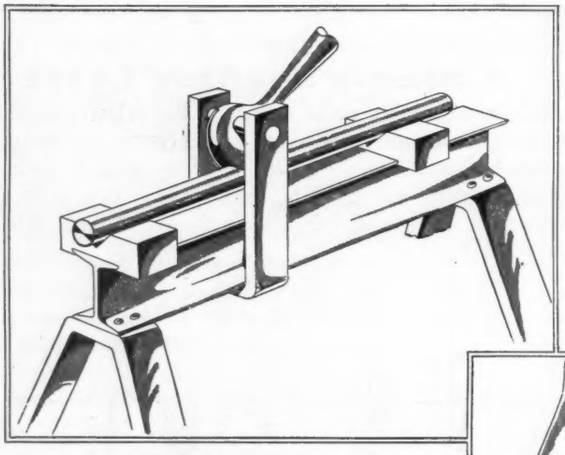
each end, and fill the crude apparatus thus constructed with water almost to the tops of the tubes, as shown in the illustration. From the level of the water in the two tubes the inequality of level between any two points compared can be ascertained with accuracy. I recently saw a backwoods mason, says S. F. Wilson in *Power,* level the foundation for a small building with a hose. He did not use the glass tubes but the result was entirely satisfactory.

However, it is only an emergency device and the greater the load on the line shaft the greater the skill required for results.

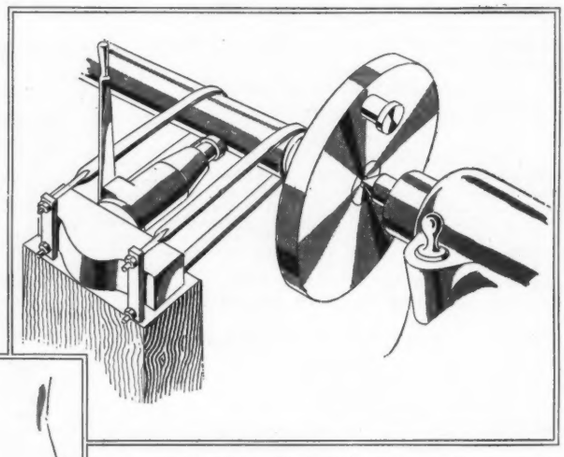
Handy Hints and Clever



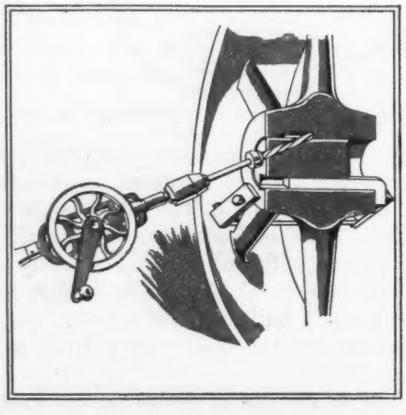
THREE DEVICES TO SQUARE UP A HAND TAP



SHAFT-STRAIGHTENING PRESS

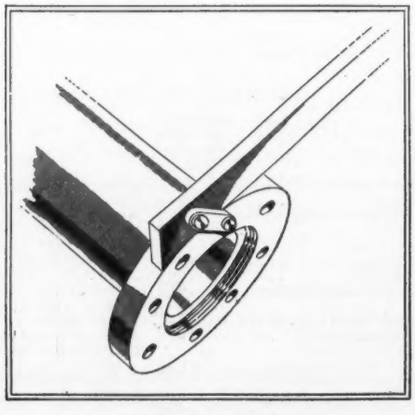


STRAIGHTENING A SHAFT



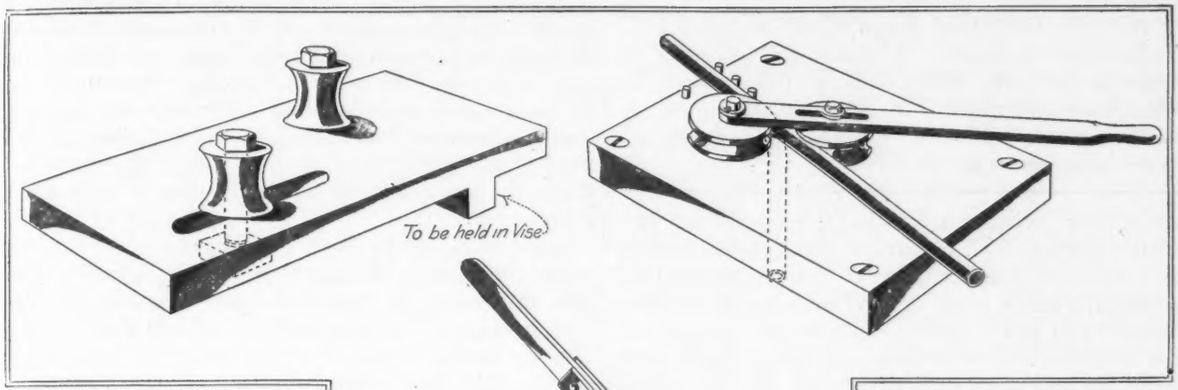
OIL-GROOVING DEVICE

BELT PUNCH



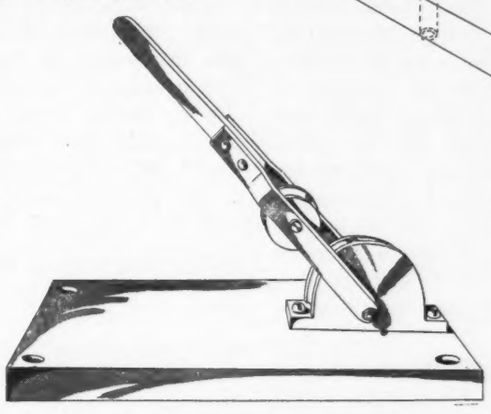
SIMPLE FLANGE WRENCH

Kinks for the Milling Plant

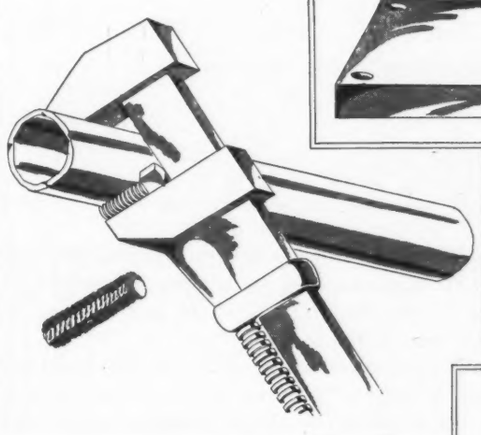


PIPE-BENDING FORM

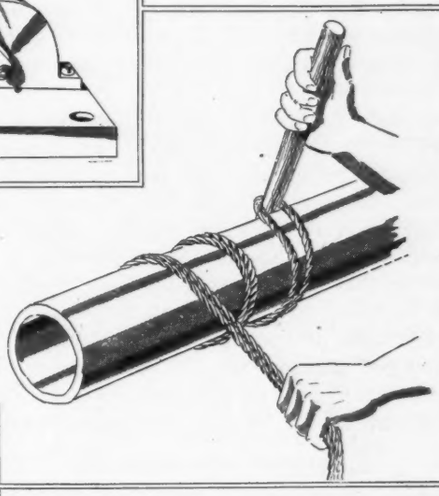
PIPE-BENDING FIXTURE



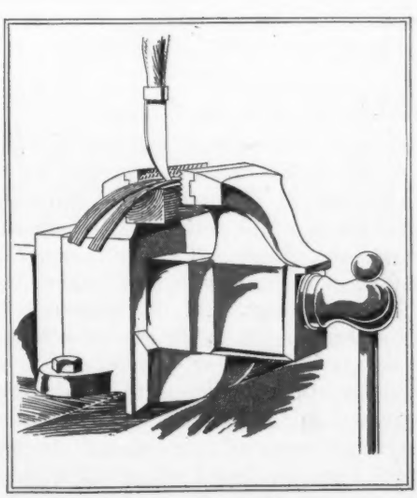
SIMPLE PIPE-BENDING DEVICE



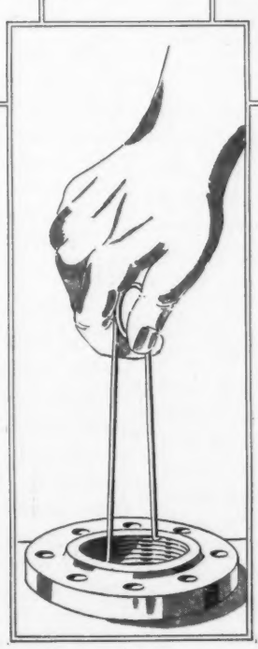
EMERGENCY PIPE WRENCH



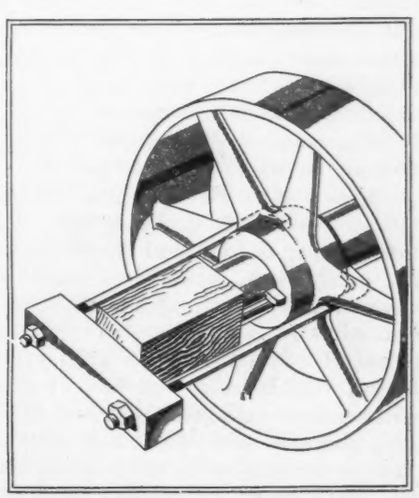
PIPE WRENCH FOR CLOSE QUARTERS



SPLITTING BELT LACE



SIMPLE THREAD CLEANER



PULLEY CLAMP

Belt-and-Bucket Elevators

By Arthur O. Gates*

SYNOPSIS—Details of design of belt-and-bucket elevators are discussed. Housing and supports should be rigid, and pulley sizes carefully considered. Wear on buckets and belts, its causes and remedies receive attention. Feeding methods and power requirements are outlined.

Most milling processes are more or less complex and involve the raising of all or part of the material treated at one or more stages of the process. For raising dry ore, coarse ore with water, slime or sand pulp, or even water, the simplest and most obvious thing to use is a bucket elevator. Occasionally the process is of such a nature and the site of the mill offers such advantages that no raising is necessary, and we have what is known as a gravity-type mill. Often the matter of elevators is the deciding consideration where choice of mill sites lies between a hillside and a flat. On the whole the elevator is regarded as a necessary machine and, as constructed and operated today, is about as reliable as any other piece of mill equipment.

The elevator familiar to the average operator is the one in which the buckets are bolted to an endless vertical belt running between head and boot pulleys; the chain-and-bucket elevator is much less common in metal mills, although used in the coal industry. Chain elevators were tried out in the metal-mining industry in the 80's and later; at that time it was the ordinary malleable link-belt that permitted grit to enter at the joints and quickly wore out. Some of the later chains with steel bushings and grit-proof features may be better adapted to the service, but there is a decided preference for belts. No further attention will be paid to chains in this article.

Supports and Housings

Mechanical and operating details have been determined largely from experience, and little experimental work has been done to determine its limitations. There does not seem to be much about it to stimulate the imagination of the efficiency engineers or the mining schools—it is just a practical man's machine. Its troubles have been largely due to light construction of the supports and of the various details, those due to improper speeds that show up at discharge points and those due to loading conditions and lack of traction on the head pulley.

The supports of an elevator should be strong and rigid as in the case of any other machine. A few are self-supporting; that is, the head shafts are carried on the housing itself, which should have heavy timbers in the corners, well-anchored to the foundation and well-stiffened to reduce vibration. In the average elevator it is possible to carry the headshaft from roof trusses or floor timbers. In this case the housing need be only a shell to retain the spills and the splashes. However, the elevators that have appeared the most satisfactory are those where the headshaft is supported from the building and the housing contains fairly heavy timbers for the purpose of stiffening it and the building at that point.

*Mechanical engineer, Mishawaka, Ind.

In order to prevent the escape of dust and water from an elevator, the shell of the housing may be of sheet metal (rarely in metal-milling plants), of matched lumber, of beveled boards or of shiplap. Occasionally two layers are used with building paper between; again the paper is fastened inside the housing and protected from the belt and buckets in motion by planks running up and down, the planks lapping in the direction of belt travel, as shown in Fig. 1.

Headshafts are frequently too light for the load they are to carry; some of them break, and in some the deflection may cause the pulley to work loose on the shaft. The stresses on the headshaft are largely those of bending, the torsion being but a third or a fifth as much and affecting the total stress but little. If bending alone be considered, working stresses in the neighborhood of 6,000 lb. will be good practice. The following equation may be used for calculations on headshafts; obtained by letting the external moment due to the load upon the shaft, $\frac{Wl}{4}$, equal the internal or resisting moment of the shaft, pS, where S is approximately equal to $\frac{d^3}{10}$,

$$\frac{Wl}{4} = p\frac{d^3}{10}$$

in which

W = Total load in pounds, due to belt, buckets, pulley, shaft, and ore or pulp;

l = Distance in inches between centers of bearings;

p = Working stress in pounds per square inch in the outer fiber of the shaft, say between 5,000 and 7,000 lb.;

d = Diameter in inches, of the shaft at head pulley.

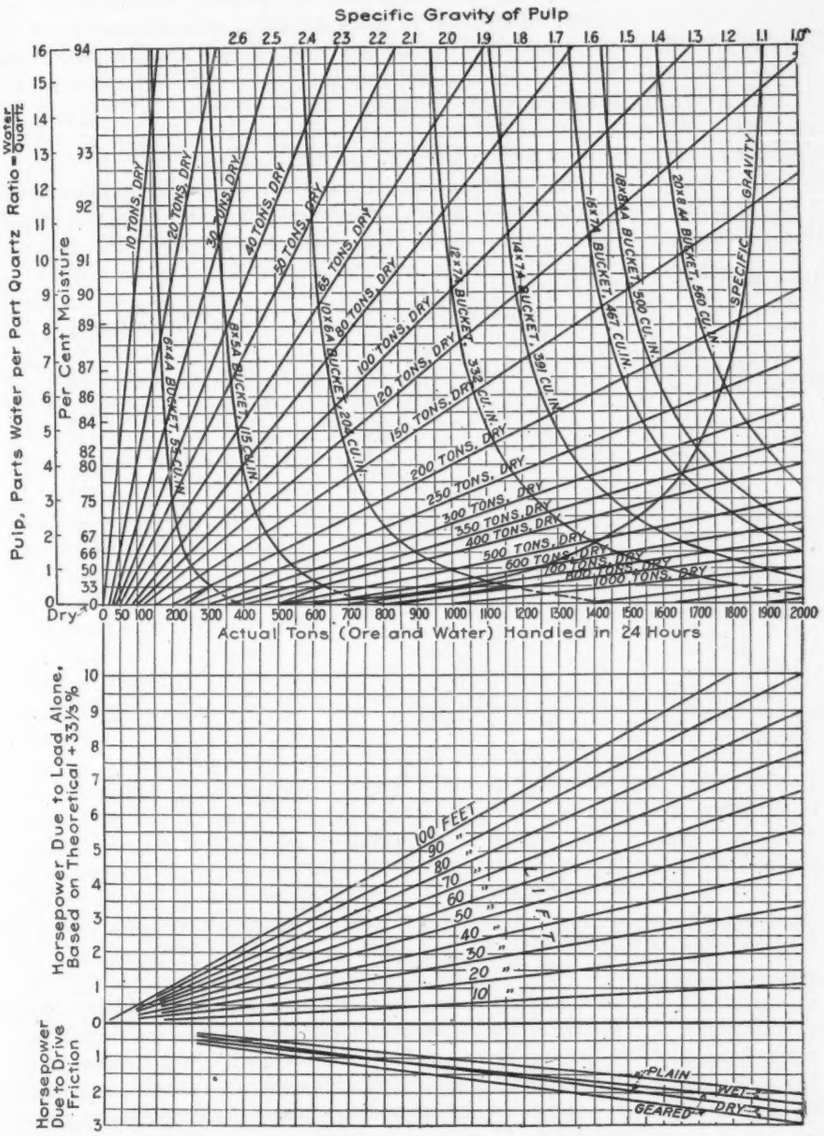
The load W may be taken as $3wh$ lb., where w is width of the bucket and h is the lift, or distance in feet between centers of head and boot pulleys. The buckets make up the greater part of the load, malleable-iron buckets being here considered. The following approximate values of d^3 of those sizes of commercial shafting most used will assist in calculations: $2\frac{7}{16}$-in., 15; $2\frac{15}{16}$-in., 25; $3\frac{7}{16}$-in., 40; $3\frac{15}{16}$-in., 60; $4\frac{7}{16}$-in., 88; $4\frac{15}{16}$-in., 120; $5\frac{7}{16}$-in., 160; $5\frac{15}{16}$-in., 210.

Requirements for Head Pulleys

The commercial rigid pillow block and the ball-and-socket pillow block have sufficient bearing surface for the load and are heavy enough; in most case a bearing of about three-quarters the diameter of the shaft is sufficient, the shaft to be bossed accordingly. Take-up bearings occasionally are used in connection with head pulleys, but more usually with boot pulleys. At the headshaft the take-up has the full load to carry, while at the boot it simply keeps the belt in its place, or may be used to increase the belt tension and the traction at the head pulley. Whether the bearings should be self-oiling or grease-cup fitted is open to some difference of opinion, my own preference being for the lower-frictioned self-oiling bearing; speeds are low and are well within the field of grease.

Head pulleys should have extra-heavy rims, from ½ to 1 or even 1¼ in. thick, depending upon the diameter of

the pulley. This provides for the wear between the belt and the pulley. So far as figures go, the stresses are no greater than in an ordinary double-belt pulley, and yet pulleys made from double-belt standards have failed by the arm punching through the rim, probably due to the way that the bucket was bolted to the belt, the full stress being thrown on a small area of the crown. A return flange at the rim of a head pulley is of no advantage, and in case of a boot pulley is a positive detriment, as it retains rock and sand within the rim, the rolling of



CAPACITIES OF ELEVATORS IN WATER, PULP OR DRY QUARTZ BASED ON 100 FULL BUCKETS PER MINUTE, EQUIVALENT TO BUCKETS ¼ FULL, SPACED 12 IN., BELT SPEED 400 FT. PER MIN.

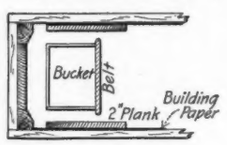
which increases the wear. The diameter of an ordinary crowned pulley of 12-in. face is ⅛ in. greater at the crown than at the edge. Some of the best mill engineers specify "high crown," which means $\frac{3}{16}$ or ¼ in. increased diameter in the above case, and proportionate increases for wider faces. Whether this high crown is a real advantage in keeping the belt true is open to debate; on very wide elevators where two buckets are used side by side and staggered, the ordinary crown is sufficient.

If the shaft be a little light, or it may be where it is heavy enough, there is a tendency for sand to work in between the shaft and the pulley hub and create or exaggerate looseness. Accordingly both headshaft and bootshaft have their pulleys put on in a hydraulic press, using straight keys. If conditions seem to require a split pulley, it would be well to use a larger shaft, bossed if desired, to cut down the deflection. If pulleys are not pressed on the shaft the accuracy of the bore is important; manufacturers of pulleys ream them to a uniform diameter, while the mechanic in the average small shop is liable to get them a hundredth of an inch larger in bore than is necessary for the fit. If the rim is specified of a given thickness, the matter of arm dimensions and whether single or double arms are to be used may be left to the reputable pulley manufacturer with safety. For elevators of considerable lift or where the material handled has some lubricating qualities (as flotation slimes), the traction of the head pulley is important. Increased traction may be obtained in three ways: By lagging with rubber belting (about 4-ply is usual), using flathead elevator bolts through the rim; by roughening the rim surface, either using the unfinished rim as it comes from the sand without machining, or a special pulley with cast bars and spaces around the periphery (slat construction), or having a series of depressions parallel to the shaft around the periphery; by increasing the diameter. In a previous article[1], the theoretical relations between diameters of head pulleys and speeds were developed and the theory was shown to check closely with practice. In that article it was shown that it was theoretically possible to use any diameter of head pulley provided the proper rotative speed is given to it, and some of the advantages of larger head pulleys, aside from increased traction, were shown. At that time I had no knowledge of pulleys and the average in mining mills was around 36 in., but today 54-in. and 60-in. head pulleys are not uncommon, and 72-in. pulleys have been considered if not installed. However, the grain elevators have been using 60-in. diameter pulleys for years and at speeds approximating those I advocated. A simpler method of studying the theoretical phases of the problem and investigations of practical elevators make advisable a slight revision of the conclusions in the previous article as to speeds. Within a body rotating upon a horizontal axis, all masses are under the influence of two forces, centrifugal and gravity, the resultant of which may be found, both in amount and direction, by the graphical method described in that previous article, to be proportional to a line drawn to the point under con-

[1]"Eng. and Min. Journ.," Oct. 18, 1913.

sideration from a point P vertically above the center of rotation, and such that under the rotative conditions obtaining, the centrifugal force upon P is just equal to the force of gravity, as X in Fig. 2. The actual force on X may be found by assuming the radius OP equal to the force of gravity, when PX may be measured to the same scale. We are not particularly interested in the actual values, except to know that the resultant force is small as it nears the point P. The rotative and linear speeds of the point P have been designated as "critical speeds," which may be of use in connection with other horizontal-shaft machines.

Without going into the matter too deeply, we find that liquids within a rotating body on a horizontal axis will tend to lie in circles about the point P, as in Fig. 2. These lines may be designated liquid-level lines, which, being equidistant from the point P, have equal pressures. Now the discharge of an elevator bucket depends upon its relation to these liquid-level lines and the critical point P, as it swings around the head pulley. A good way to study this is to take a piece of plain paper filled with concentric circles and rotate over it a piece of tracing paper on which have been drawn to scale the elevator-pulley circle and one or more buckets. The center of the concentric circles P should be at the point where for the speed considered, W, the gravity force, equals C, centrifugal force, equal to $\frac{Wv^2}{gR}$, from which $v^2 = gR$; v being velocity of point in feet per second, $g = 32.2$, and R = radius in feet per minute. Figs. 3, 4, 5 and 6 show such studies. The eye can sometimes catch glimpses of what is happening in a bucket as it reaches the head pulley. For instance, in a dry elevator the rock would be jerked to the lip of the bucket at the instant it touched the head pulley, and under favorable circumstances the liquid-level lines might be caught.



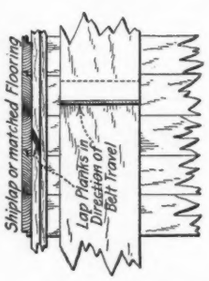


FIG. 1. HOUSING SECTION

If a 36-in. pulley has a rotative speed that makes the belt travel at 300 ft. per min., the standard practice of 10 or 15 years ago, the point P will lie well outside the path of the buckets (Fig. 3), the pulp will be forced to the belt when at its highest point and will be discharged with the velocity of the belt, which, being slower than that of the bucket tip, may allow some of the pulp to be trapped within the bucket and be carried down into the boot. This condition is no doubt responsible for the practice that puts the divider between the discharging pulp and the descending buckets very low down, as low as on a 45° line from the bottom of the head pulley.

I previously advocated making the critical speed that of the bucket tip. Fig. 4 shows how this works out—still with a tendency for the pulp to flow down on the belt and to discharge with the velocity of the belt.

If, however, the critical speed be that of some point well within the head pulley, as in Fig. 5, the pulp will be squeezed out of the bucket long before the bucket reaches the top position and may progress by steps around the head pulley with splashes down into the boot. I have been told of a case where a belt was run at about double critical speed and it discharged all on the rising side.

Much nearer the ideal condition is shown in Fig. 6, the critical point being 2 or 3 in. out from the pulley, there being no flow to the belt and no probable splashing on the rising side. Based upon this ideal, pulley and belt speeds for all diameters have been plotted in Fig. 7, while two additional curves are drawn in, one for critical speed that of the belt, and the other, critical speed that of the bucket tip, as previously proposed. Probably these should be taken as the limits, although Timber Butte Milling Co., at Butte has a 60-in. pulley running at a little over 600 ft. per min., belt speed, and it discharges from a point well back of the top, and into the receiver above the horizontal center line of the pulley.

Driving Pulleys and Belts

Headshafts are driven through a pair of spur or bevel gears, or by means of an exceptionally large pulley at a comparatively low transmission-belt speed. The product

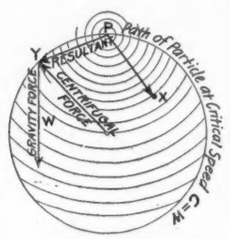


FIG. 2. LIQUID-LEVEL LINES IN BODY ROTATING ON HORIZONTAL AXIS

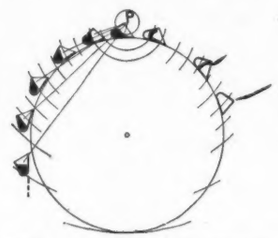


FIG. 4. CRITICAL SPEED AT BUCKET TIP

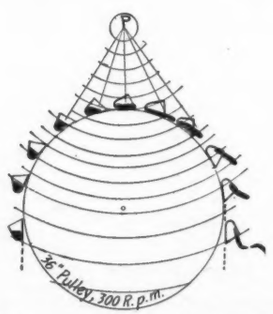


FIG. 3. LOAD AND DISCHARGE, 36-IN. PULLEY, 300 FT. PER MIN.

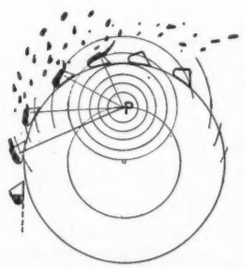


FIG. 5. EFFECT OF EXCESSIVE SPEED

of diameter by face of this driven pulley should be nearly equal to that of diameter and face of the head pulley.

For all but very short-lift elevators the spur-gear drive is the most common. A well made cast-tooth gear should be about as satisfactory as any, its proportions determined by Lewis' formula for gearing with not over 5,000 lb. as the value of the static stress. Unless gear patterns are well taken care of and gone over carefully before going into the foundry, the teeth will be uneven in pitch and not lie on a true pitch circle, and thus it is we have noisy gears. Some prefer cut gears on account of probable increased efficiency before wear is appreciable. On account of the hard skin on the cast tooth the wear will be less until the skin is worn through. Some prefer cast-steel gears. Probably it is well to use a cast-steel pinion, because its tooth is weaker than that of its mating gear, and each tooth has several times the contact and wear. It is all a matter of giving the gearing sufficient wearing

surface; they all wear, and as soon as wear becomes appreciable, all theoretical advantages disappear. One point that is important is to keep the gear and pinion in line and well tied together by means of a double-adjusting baseplate; this is well worth the little added expense.

If objection is made to the noise of spur gearing, mortise gears may be used, the wood teeth being in the driven gear, both gear and pinion being cut. The average mining man will say that mortise gears belong to the dark ages, but there are many still in use. They are still being made in fair quantities, and one of the largest mining companies in the world continues to use them on some of its largest hoists, the cogs lasting in some cases six to eight years.

High-reduction worm gears have no place on elevator heads. They are a delusion and a snare, usually fearfully inefficient, the inefficiency showing in the rapid wear of the teeth. The efficient worm gears have no greater ratio of speed reduction than it is possible to obtain with ordinary gears.

If the elevator head is rather inaccessible from the mainshaft of the mill transmission, it can be driven by motor or by an up-and-over or around-the-corner rope drive. Considerable excess capacity should be provided in the motor to take care of starting and slipping loads. The motor capacity should be nearly double that given in the chart. Two or three ropes will ordinarily handle the elevator, the gearing being so arranged that the speed ratio between the driving and driven sheaves is within rope-drive limits.

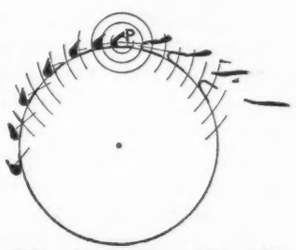


FIG. 6. LOAD AND DISCHARGE AT RECOMMENDED SPEEDS

The total lift possible by one of these elevators is limited by the traction of the head pulley and by the ability of the belt to stand the pull. In a following table lifts out of ordinary practice are suggested, it sometimes being stated that if one wishes to lift over 60 or 70 ft., two elevators should be used. I do not agree with this, for in grain-elevator practice, lifts of 140 ft. are used and probably more. It may be necessary to space the buckets farther apart in order not to have a whale of a belt.

The majority of mining districts use the malleable A or AA bucket, while in southwestern Missouri and thereabouts the buckets are of steel, all of the same cross-section, and sold at so much an inch. About one-third of the capacity of the bucket is available, and it is perhaps better to figure on quarter capacity for ordinary duty and to take care of sudden rushes of feed.

In order that the buckets discharge freely, holes from ¼ to ⅜ in. in diameter, about 5 in. apart, are drilled in their bottoms. This practice, I am told, was started in Colorado years ago. It is used in the Cœur d'Alenes and was called to my attention by Mr. McGillivary, foreman of the Timber Butte mill, to whom I am indebted for many practical suggestions and corroborations. This sounds like bailing with a sieve, but it works out nicely. Probably there is a complete change of the pulp in a bucket from the time it starts up until it reaches the head pulley. The holes prevent the sands from concentrating in the bottom of the bucket. At other places jets of water to clean out the buckets appear to be necessary.

The spacing of the buckets is from 12 to 20 in., it being generally recognized that there should be sufficient room between them to prevent interference in filling—a spacing of twice the projection seems to approximate practice. When the bucket is bolted directly to the belt, there is sufficient relative motion between the two to cause considerable wear; leather or rubber washers are used to keep them apart and to allow free passage to the sand and grit which otherwise might work in between. Sometimes the belt has been protected from the impinging stream of ore by a short piece of belt running perhaps halfway to the next bucket above and to which the protected bucket may or may not be fastened. As this has not become general practice, it may have been because sand could get between the belts and cause wear on the belt.

The big item of first and operating cost is the belt. Its strength and number of plies should be based upon the load it is to carry, the load increasing directly as the lift

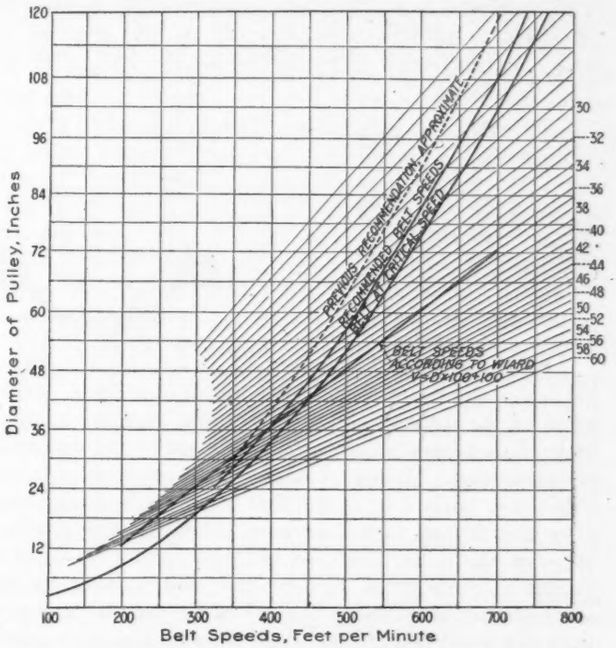


FIG. 7. ELEVATOR SPEEDS FOR DIFFERENT PULLEY DIAMETERS

if bucket spacing remains constant, and increasing spacing slightly with the width. As larger head pulleys with increased belt speed would be used for those lifts that are now considered outside the realm of bucket elevators, the spacing of buckets could be increased for the same capacity, and the belt pull need not be excessive. In the table following, some consideration has been given to this; the number of plies of the belt is rather tentative, based on experience and judgment rather than calculation.

TABLE 1. BELT-AND-BUCKET ELEVATOR DATA

Height C.–C., Ft.	Min. Diam., In.	Recommended Diameter	Belt, No. Plies	Height C.–C., Ft.	Min. Diam., In.	Recommended Diameter	Belt, No. Plies
20	24	30	5	80	60	84	12
30	30	36	6	90	66	96	12
40	36	48	7	100	72	108	14
50	42	54	8	120	84	120	16
60	48	60	10	140	96	132	18
70	54	72	10	160	108	144	20

The life of the belt depends upon external conditions rather than upon the normal stretching and releasing of stress as it picks up and discharges the load and bends over the pulleys. Besides the wear mentioned in the previous paragraph, what is usually a greater wear takes

place between the belt and the pulleys. Boot conditions, some of which may be reduced, are responsible for this. In many plants the material is fed directly into the boot, or even where the ore is supposed to be fed into the buckets there are spills, the boot is filled up with coarser material, some of which gets between the belt and the pulley, is pressed into the belt and acts as a grinding medium for both pulleys and belt. Old rubber belting on mill scrap piles will show several plies worn through on the pulley side, the impressions of the elevator bolts indicating the side. On small pulleys with not enough tractive surface to prevent abnormal slips of the belt, the wear will be excessive and the loss of power serious. So far as I can determine, it is better to divide up any rubber covering between the two sides of the belt.

Boot pulleys will average about 6 in. in diameter less than head pulleys, and even more metal should be put in the rims if anything, for the boot pulley is working down in the sand and rock. It is even more necessary to press in the shaft to prevent sand working in and wearing it loose. Various types of boot bearings are used, depending upon the conception of the difficulties there in the mind of the deviser. In southwestern Missouri a loose-fit hard cast-iron bearing is stuck down in the dirt with no protection. When it wears out, another is used. Others use fairly long shafts that bring the bearings away from the trouble; another uses bearings with stuffing-boxes on the pulley side, the bearings having closed ends on the opposite sides. In another case a collar on the shaft fits into a recess on the end of the bearing and protects the wearing surfaces. All these should have grease lubrication, depending upon a ring of grease to keep the dirt out. Take-ups are really nothing more than these bearings so mounted on a frame that a screw may be used to bring the boot pulley into proper relationship with the belt. Manufacturers' catalogs show quite a variety.

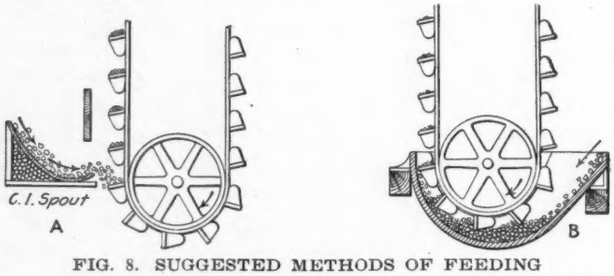


FIG. 8. SUGGESTED METHODS OF FEEDING

Two special types of boot pulleys have had considerable success—the one used by the Utah Copper Co. and its subsidiaries and the M. P. Boss pulley, both of which, I believe, have been described before in the technical press. The Utah pulley uses a fixed axle and has an oil well in the hub, the ends of which are closed with stuffing-boxes. The Boss pulley may be said to be rimless, for in place of rim are a number of bars connected to a double-cone hub, the idea being to give less contact, to let the pieces of rock and sand fall between the bars and to deflect them out of the pulley by the cone.

Methods of Feeding Elevators

Boots run all the way from a close-fitting cast-iron or steel affair to a cellar as big as the ordinary hotel room. Where the rock is coarse it is desirable to spout directly into the buckets and let the few spills be picked up by a following bucket, usually in a close-fitting boot. In some dry elevators a steel plate close up to the path of the buckets is used in a wooden boot; it is hinged at one end, and the other has a small ratchet drum so that it can be quickly emptied and closed again. If the material handled is fine sands or slimes with plenty of water, the cellar boot is all right, the spouting can be led in anywhere and the agitation of the passing buckets keeps things stirred up and from settling and piling up. Provision should be made for emptying the boot by means of a door or trap.

Except where very fine material is discharged into the boot at any convenient place, the best practice spouts into the rising buckets at a point high enough up so that there is an additional bucket below to catch the spills. Some say that the material should enter at a point 18 in. above the center line of the pulley, others on a 45° line through the center of the shaft. They all amount to the same thing. In southwestern Missouri, where they do not spout into the buckets but into the boot, the claim is made that the impinging sharp rock particles cut the belt more than the wear caused by digging out of the boot with its extra wear on buckets and increased power consumption.

Mill men will agree that it is theoretically desirable to load the buckets with the least shock, which might be accomplished by spouting the feed in the direction of motion of the buckets. Using a scheme as shown in *A*, Fig. 8, the relative velocities of feed and buckets would be about one-half of that where the spouting is straight in; *B* is a sort of reverse of the present cast-iron boots, spouting in the direction of motion of the buckets. In both cases a suitable boot must be provided. For the *B* case a 3-ft. free fall would give the velocity of the buckets to the feed for ordinary elevators.

The average bucket elevator is vertical. Sometimes the line of the rising buckets is inclined ahead from 2 to 6 in., the theory being that the bucket should "lie" on the belt and so reduce the pull on the elevator bolts. I question whether this practice has any advantage over a truly plumb belt. Some belts are inclined as much as 10° in the direction of the discharge. Except as a horizontal displacement is obtained, there is no advantage, and the belt must be kept tighter. That the horizontal displacement may be a distinct advantage in some cases goes without saying. In some of the Lake Superior mills are elevators of about 20-ft. centers running on an incline of about 45°, raising reasonably small quantities of table middlings. The belts are 4 and 6 in., pulleys about 30 in. diameter with a single supporting roll midway between the pulleys under the carrying side. Speed is about 15 ft. per min., and the feed is spouted into the buckets. In western Nevada I saw a belt conveyor inclined about 35° or more, handling fine dry sands, strips of old belting being riveted on at short intervals to hold the material; thus the gap between the elevator and the conveyor is spanned.

It is probably unnecessary to refer to the elevator that is a prominent feature of gravel- and rock-crushing plants for construction purposes, some of which find their way into the mining game. The belt rises at an angle about 22½°; rubber belt is generally used. The buckets are of steel, V-shaped and close-spaced, rollers are placed under the rising belt at short intervals, head pulleys are relatively small and belt speeds are around 200 ft., per min.

On the flat mill sites of southwestern Missouri and its allies in the neighboring corners of Kansas, Oklahoma and Arkansas, the elevator seems to thrive best. There

they can make two elevators grow where one was before. Their practice must be recognized as designed to fit the local conditions, for in addition to the flat mill sites they have an ore which invariably breaks, large or small, into near relatives of the Indian arrow-head with never-failing cutting edges, and they use a flood of water in their jigs. Perhaps 15% of the power in the mill is for lifting water. Five elevators make a very ordinary mill; there must be close to 400 mills in the district—a grand total of two thousand elevators. Feed is spouted into rather open wooden boots with the bottom planking close up to the path of the buckets. Here the pulley sizes are smaller than in other camps—24, 30 and 36 in. are the customary diameters of head pulleys, while boot pulleys are 20, 24 and 30 in., some of them crowned and some of them straight face. Lifts are rather low except in the case of tailings elevators, which may run to 50 ft. Where additional elevation is needed on a tailings pile, a second or a third elevator is added; they call them "dummies." The belt is somewhat inclined, the housing conforming to the belt on the rising side and vertical on the descending. Belt speeds are around 300 ft. per min., although one or two are up around 500 ft. per min.

Belt elevators are reasonably efficient, probably more so than the centrifugal pump except in cases where the head pulley does not afford sufficient traction or where not enough attention is paid to details. The chart gives in convenient form the data on capacity and horsepower that one ordinarily has to consider when selecting an elevator and providing the drive. It checks fairly well with examples from practice. To select an elevator for capacity, the point is found where the horizontal line of moisture or water ratio intersects with the diagonal of equivalent dry tons; the curve to the right of that point indicates the bucket to be used. The equivalent dry tons per 24 hr. is found in the following manner: Suppose a 60-in. head pulley is used, buckets to be spaced at 16 in., and considered to carry one-third capacity. From Fig. 7 we find that a belt speed of 500 ft. per min. is about right; there will be 125 full buckets per minute. If 250 dry tons per day, carrying 6 parts of water, is to be raised, the equivalent dry tons on a 100% full-bucket basis will be 200, so we use the diagonal of 200 tons dry and find that a 20-in. AA bucket should be used. The specific-gravity line was drawn in at the time of making the diagram, and was left in, thinking it might be of value to those whose daily business requires consideration of pulps. It connects the specific-gravity values at the top with the pulp ratio and moisture values at the side. Note that for dry rock the specific-gravity relation no longer holds. There are air voids between the pieces of material, and accordingly the curves are stopped at the 33% moisture line and come back as straight lines to the dry line on a basis of 20 cu.ft. to the ton. The vertical lines in the diagram represent actual tons of live load of ore, water and other material lifted in 24 hr. The horsepower in the middle diagram is that considered as due to load alone, while the lower part takes care of the friction in the bearings and drive.

Many of the practical data used in this article have been taken directly from practice. The section of the housing in Fig. 1 is from the mill at Cananea; perhaps David Cole will not recognize the offspring. If anyone finds anything of value belonging to him herein, it is a pleasure for me to return it to the owner.

Flotation in Joplin District

By Lucius L. Wittich*

Several experimental flotation plants have been installed in the Joplin district, but with one exception (that of the Mining and Flotation Co.) of Denver, none has yet proved successful. The first experiment was conducted two years ago on slimes from the Priscilla mill of the Underwriters Land Co., west of Joplin. This plant is no longer in operation. The Picher Lead Co. has at Picher, Okla., an experimental plant that is not yet productive. The American Zinc, Lead and Smelting Co. is experimenting with flotation at its Prosperity, Mo., mines, but has not yet reported profitable operation. Other smaller experiments along this line have been tried.

The plant of the Mining and Flotation Co. of Denver is on a lease of the Granby Mining and Smelting Co., in Leadville Hollow, two miles northwest of the business center of Joplin. The work of bringing the plant to a point of profitable operation has been in the hands of S. P. Warren, who holds the secret on the nature of the composition of oils employed. The chief ingredient is pine oil, the cost of which is 50c. per gal. The plant is handling 80 tons of ore a day, taken from a tailings pile of the old Gravity mill, operated many years ago. The tailings have already been run through one mill that operated on the lease several years ago, and the metallic contents down to barely more than 1% have already been removed. This extremely thin dirt is yielding about 1% blende, and a small percentage of galena, the daily recovery in 10 hr. being about 1,600 lb. of concentrate out of 80 tons of tailings handled. Half of the recovered concentrates comes from a flotation cleaner and a single Arbuthnot table, used to improve the grade of the concentrates, while the other half comes from four Wilfley sand tables that handle the coarser ore that does not pass through the flotation cleaner.

Although the plant has not yet reached the state of perfection that the operators expect of it, the approximate daily cost of operation is $20, while the concentrates recovered are valued, at present prices, at $50 to $60.

Two teams and drivers scrape the tailings to the mill hopper, where the ore is elevated to a revolving screen of 1-mm. mesh, the oversize being discarded, as no crushing devices are employed. Undersize passes into a hopper from the bottom of which the coarser ore is elevated by a screw classifier into a separate hopper whence it passes onto the four sand tables. The fine ore, escaping elevating by the screw, passes into a settling tank from the bottom of which it is drawn off through four openings and pumped up to the top end of a six-cell flotation cleaner. From ½ to ¾ lb. of oil is used per ton of dry slime. The oil froth, after leaving the Arbuthnot table at the bottom of the flotation cleaner, passes back, along with the middlings from the table, to the settling tank and is used again.

In each of the six cells of the cleaner is an impeller that revolves at a peripheral speed of 1,100 ft. per min., thus whipping the oil, water and ore mixture to a froth that rises to the surface of the water in a layer about 2 in. thick. From each cell this froth is skimmed off with a slowly revolving scraper. The froth goes direct to a launder that feeds onto the cleaning table, where clean

*Joplin, Mo.

water washes the oil free from the ore. From the sixth cell are drawn off the tailings, consisting of material that does not float in the oil froth.

The dry slime that passes into the flotation cleaner, having been relieved of a large percentage of coarser ore and much gangue matter, passes into the flotation treatment materially enriched above its formation when being scraped into the first hopper from the tailings heap. The loss of blende in the flotation tailings is reduced to a minimum. The little plant is operated by a 50-hp. motor, and there is enough material in sight to keep it in operation for years.

Stamp Milling at Alaska Treadwell

The 240-stamp mill of the Alaska Treadwell company in 1915 had a duty per stamp day of 4.31 tons. One pound of chrome steel in the shoes crushed 2.7 tons of ore and 1 lb. in the dies crushed 5.83 tons. In the 300-stamp mill the duty per stamp day was 5.31 tons and 1 lb. of chrome steel in the shoes crushed 2.44 tons of ore and in the dies crushed 4.09 tons. The cost of milling was $0.312 for both mills.

DETAIL COSTS OF MILLING

	240-Stamp Mill Cost per Ton	300-Stamp Mill Cost per Ton
Labor Cost:		
Crushermen and helpers	.....	$0.002
Laborers	$0.001	.003
Feeders	.039	.025
Amalgamators	.025	.016
Vannermen	.023	.015
Sampler	.002	.001
Foremen	.006	.004
Carpenters	.002	.003
Engineers	.005	.....
Total direct labor	$0.103	$0.069
Supplies:		
Shoes	$0.015	$0.016
Dies	.003	.003
Cams	.004	.001
Bossheads	.005	.008
Tappets and keys	.002	.004
Mortars	.005	.007
Mortar extras	.003	.004
Screens	.003	.002
Copper plates	.....	.001
Quicksilver	.004	.006
Lubricants	.001	.....
Vanner belts	.002	.012
Belting	.001	.003
Miscellaneous	.005	.010
Total direct supplies	$0.053	$0.077
Subsidiary Accounts:		
Building repairs	$0.013	$0.004
Electrical repairs	.002	.004
Mechanical repairs	.018	.012
Power	.050	.054
Train service	.001	.001
Assaying	.002	.001
Douglas Island general expense	.014	.009
Electric lights	.002	.002
Steam heat	.005	.002
Tailings expense	.....	.008
Pumping salt water	.010	.006
Compressed air	.002	.001
Central crushing	.037	.036
Central tramming	.014	.015
Experimental	.002	.001
Total subsidiary accounts	$0.172	$0.156
Total costs	$0.328	$0.302
Recapitulation:		
Crushing	$0.038	$0.038
Tramming	.014	.016
Stamping	.210	.189
Concentrating	.066	.059
	$0.328	$0.302
Labor	$0.103	$0.069
Supplies	.053	.077
Subsidiary accounts	.172	.156
	$0.328	$0.302
Tons ore crushed	349,153	551,058
Tons sulphurets saved	6,618.91	12,558.34

Sulphuret Expense, 19,177.25 Tons Total

	Cost per Ton
Labor	$0.436
Supplies	.090
Train service	.087
Sulphuret car expense	.101
Assaying	.020
Cyaniding	3.244
Douglas Island general expense	.062
San Francisco office, charges on cyanide bullion	.344
	$4.384

Air-Lifts at a Cyanide Plant

By Paul W. Gaebelein*

At the cyanide plant of the Baker Mines Co., Cornucopia, Ore., the pulp, both sands and slimes, is handled entirely by air-lifts. In the following brief description, two of the air-lifts are taken up in detail and illustrated, the first handling sands and the second slimes pulp.

The ore, after being crushed in stamps to 25-mesh, is classified in a duplex Dorr classifier, the sands being lifted by air to the leaching tanks and the slimes being treated in three Dorr agitators 20 ft. diameter and 16 ft. deep, three Dorr thickeners, and a Portland continuous filter. The plant has three air-lifts for pumping sands and slimes, and compressed air is also required for the operation of the Dorr agitators and the filter.

Compressed air is supplied by a Sullivan compressor, class WG3, belt-driven, size 14x12 in. This compressor

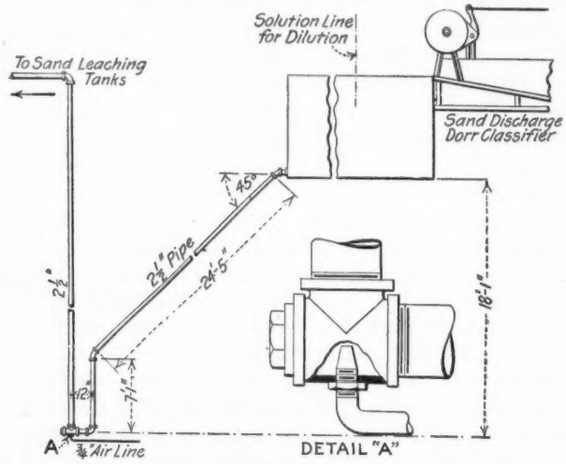


FIG. 1. DETAILS OF SAND LIFT

is operated at 120 r.p.m., and at 5,000 ft. altitude has a capacity of 215 cu.ft. per min. Air is compressed to 15 lb., which is sufficient for the operation of the air-lift system. The power consumption under these conditions is 12.5 hp.

Fig. 1 illustrates the sands lift. As the sands are discharged from the Dorr classifier, they drop into a mixing box in which they are diluted with barren solution in the proportions of 4 of solution to 1 of sand. This rate of dilution has been found satisfactory both for the successful operation of the air-lift and the automatic distributors with which the leaching tanks are equipped. The sketch shows the construction of the lift in detail. The amount of sand handled per day is 40 tons, diluted with 160 tons of barren solution. Fig. 2 illustrates the air-lift between No. 2 and No. 3 thickeners. The situation of No. 2 thickener is such that it requires a rather long pipe line to transfer the pulp to a point from which it can be lifted to No. 3 thickener. The lift is rather

*Mill superintendent, Baker Mines Co., Cornucopia, Ore.

a high one, owing to the fact that No. 3 thickener is at sufficient elevation to allow the pulp to flow by gravity to the filter-stock tank and thence to the filter. The slimes handled are very fine and colloidal. Fig. 2 gives the air-lift in elevation. It handles approximately 25 tons per day of slimes at a dilution ratio of 1:1, or 50 tons of pulp per day. The thickness of the pulp delivered by the thickener is regulated by placing nozzles of various sizes in a reducer placed as shown in the sketch. The reducer is from 4 to 2 in., and the nozzles are 2-in. plugs drilled through the top. Each thickener is equipped with a set of nozzles, and these are changed as the flow of pulp demands.

While the air-lift system of handling pulp is not the most efficient, it has numerous advantages over the use

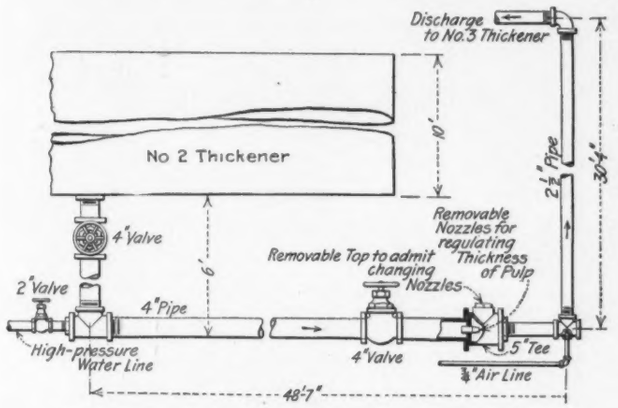


FIG. 2. AIR LIFT FROM SLIME THICKENER

of sand and slime pumps. Some of these advantages are low first cost, simplicity, absence of repairs, avoidance of delays due to repacking and repairing pumps and practically continuous operation. The system at the Baker Mines Co.'s plant has given satisfaction and practically continuous service.

Hollinger Mill Operations, 1915

During 1915 the Hollinger Mill, at Timmins, in the Porcupine district of Ontario, treated a total of 441,236 tons, of which 334,750 tons came from the Hollinger mine and 106,486 tons from the Acme. The total value of this ore was $3,384,666, or $10.11 per ton. The mill treated 917 tons per day, operating an average of 93.8% of the possible running time. The mill duty per 24 hr. of actual running time was 978 tons, and the stamp duty per 24 hr. of running time was 14.72. Of the value unrecovered, $81,763 was in the form of concentrates that were stored for re-treatment and $133,090 was lost in tailings. The recovery amounted to $3,169,813, making an extraction of about 93.65%.

The amount of cyanide consumed per ton of ore was 0.574 lb.; of lime, 1.896 lb.; of zinc, 0.467 lb.; of acid, 0.0032 lb.; of lead acetate, 0.0021 lb. There were 1.909 tons of solution precipitated for each ton of ore treated, and 0.244 lb. of zinc was added for each ton of solution. The accompanying table shows the distribution of all milling costs, which total up to almost exactly $1 per ton treated.

During the year 9,500 tons of concentrates were stored for re-treatment, and now that the plant for treating this material has been put into proper shape, it will be gradually reclaimed until it has all been treated. There are in process of installation extra tube mills and a screening plant, by means of which it is proposed to relieve the stamps of the duty of further crushing on that portion of the ore that comes from the breaker in condition fine enough for direct tube milling. The continuous-decantation plant is being increased by the addition of two rows of 40-ft. tanks. Six Dorr agitators, 26 ft. diameter by 18 ft. deep, have been installed to secure a longer period of treatment for the ore. The concentrating plant has been rearranged to make room for the agitators, and a tube mill has been installed in

DISTRIBUTION OF MILLING COSTS

Account	Labor	Stores	Total	Per Ton of Ore Milled
General milling charges	$7,115.83	$8,662.16	$15,777.99	$0.036
Superintendence	10,183.89	.....	10,183.89	.023
Tailings disposal	3,364.23	2,356.81	5,721.04	.013
Lighting	263.54	2,781.30	3,044.84	.007
Heating	1,594.35	8,200.72	9,795.07	.022
Shoveling in bins	3,444.55	.....	3,444.55	.008
Crushing	14,124.04	13,038.12	27,162.16	.062
Conveying	10,659.67	8,484.97	19,144.64	.043
Stamping	13,906.04	34,669.22	48,575.26	.110
Classification and tube milling	11,142.92	77,709.27	88,852.19	.202
Concentration	10,662.40	4,821.65	15,484.05	.035
Handling concentrates	1,389.89	1,763.40	3,153.29	.007
Treating concentrates	1,231.21	1,246.66	2,477.87	.006
Handling pulp	4,621.18	6,420.08	11,041.26	.025
Thickening	2,471.40	1,803.66	4,275.06	.009
Agitation and continuous decantation	8,055.10	2,258.76	10,313,86	.023
Filtration	10,082.30	10,037.87	20,120.17	.046
Neutralizing	1,334.33	4,533.17	5,867.50	.013
Clarifying and precipitation	2,796.04	29,283.96	32,080.00	.073
Refining	6,584.66	11,304.81	17,889.47	.041
Pumping solutions	5,168.51	6,211.36	11,379.87	.026
Cyanide	6.92	63,352.18	63,359.10	.144
Cleaning mill	6,245.94	.....	6,245.94	.014
Alterations	5,337.98	4,386.53	9,724.51	.022
Assaying	3,067.82	1,825.57	4,893.39	.011
Maintenance of buildings	474.39	147.31	621.70	.001
	$145,329.13	$305,299.54	$450,628.67	$1.022
Less cost of treating 106,486 tons Acme ore			116,079.21	1.090
Cost on 334,750 tons Hollinger ore			$334,549.46	$0.999

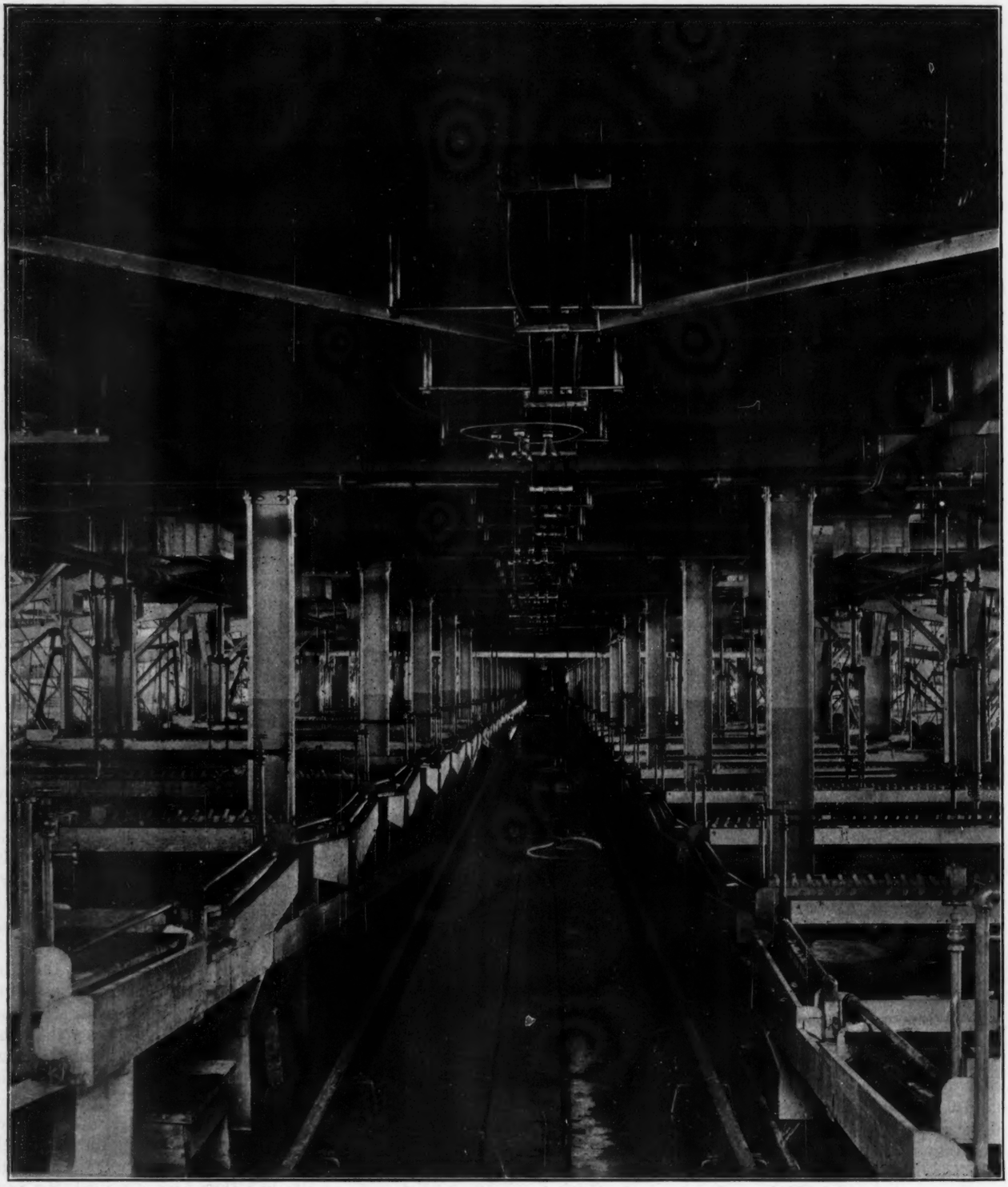
circuit with the two smaller agitators for treating concentrates. It is expected that by means of these alterations the capacity of the mill will be raised to 1,900 tons per day and that a slightly improved extraction will be obtained, owing to the increased agitation provided.

A Flotation Mystery

At the joint meeting of the New York sections of the American Electrochemical Society and the American Institute of Mining Engineers, held at the Chemists' Club, New York, May 12, Professor Richards told of flotation experiments that were carried out at a Tennessee zinc plant where a mill of commercial size was built, based on the result of laboratory tests which were very flattering. The mill operations did not coincide with the results obtained in the laboratory, and for a long time the reason for the discrepancy was a mystery.

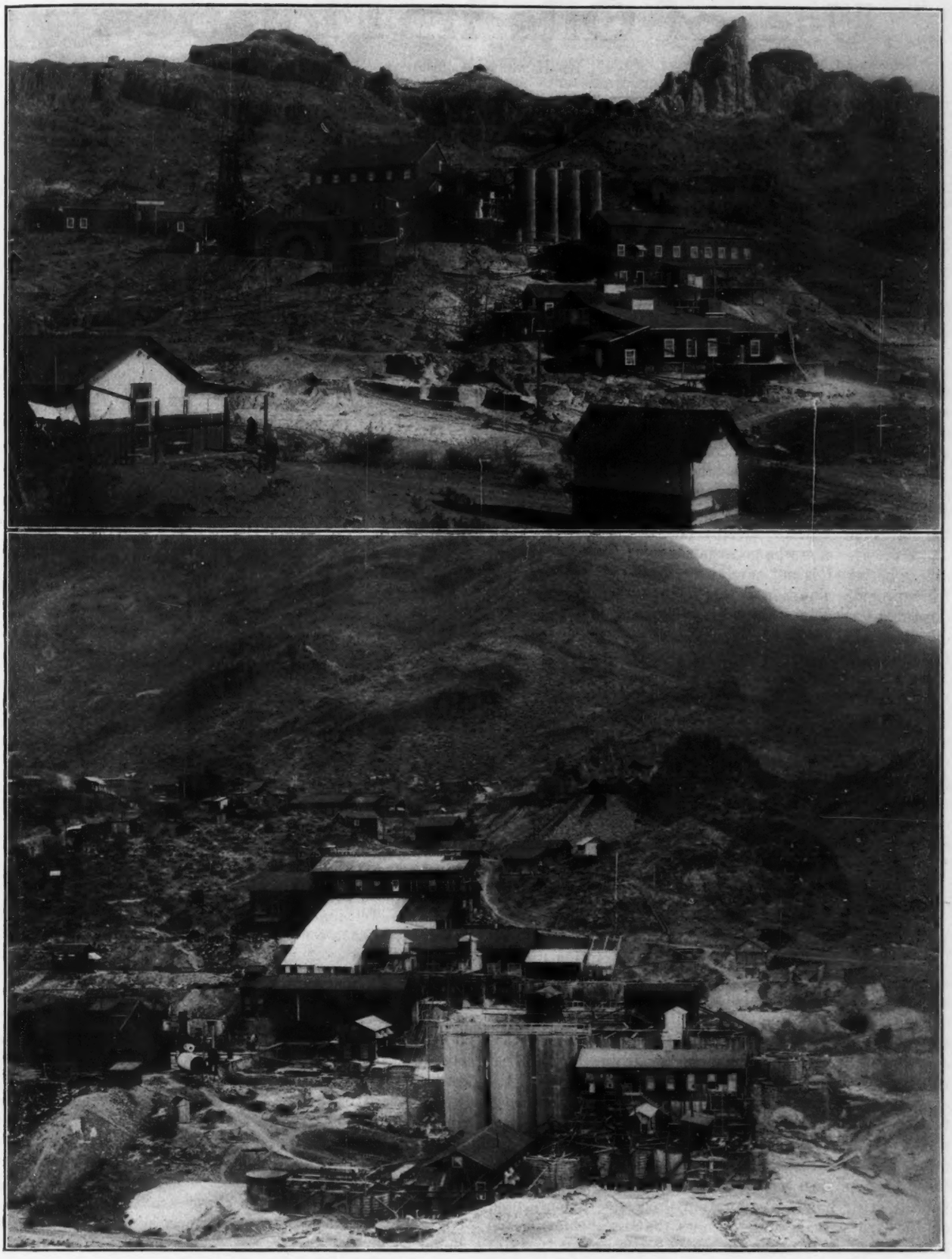
Finally, question arose as to whether the fact that the laboratory tests were carried out in a flotation machine made of brass and the mill units were made of wood did not account for the difference, assuming that the sulphuric acid had attacked the brass of the flotation machine sufficiently to get some copper sulphate in solution. Copper sulphate was experimentally added to the wooden tanks in the plant, and as satisfactory results were secured as had been previously obtained in the brass cell in the laboratory. Professor Richards said that, although the satisfactory results had thus been obtained, the particular rôle that the copper sulphate played in this instance had not been explained.

Photographs from the Field



INTERIOR OF THE CALUMET & HECLA CONCENTRATOR AT LAKE LINDEN, MICH.

This new steel-frame building incorporates all that is most modern and best in concentration practice. One of the important table floors is shown in the illustration



TWO PRINCIPAL MILLING PLANTS OF THE OATMAN DISTRICT, ARIZONA

*The upper view is of the Tom Reed mill, at Oatman, center of the newly developed gold field, and the lower is of the Gold Road mill, at Gold Road. Neither mill is a result of recent excitement in the district

Use of Oils in Flotation

By Herbert A. Megraw

SYNOPSIS—Various theories of the functions performed by oils in flotation processes have been propounded. The reduction of surface tension and the preferential oiling of mineral particles are the most prominent of these duties. The way of their accomplishment is discussed and some examples are given of how it works out in practice.

The oils used in the flotation process are many and their qualities vary within extremely wide limits, so that it appears that with ores of certain classes certain oils may be used, while with different ores oils having different qualities must be made use of in order to produce successful results. It has seemed apparently true that any particular kind of oil is not necessarily applicable to all ores, or perhaps it would be better to say that the same oil will not produce equally successful flotation results with all ores. That has been the theory heretofore and is an assumption that most metallurgists have taken for granted and have not seriously questioned. Apparently, however, the statement is not so broadly true as has been believed, and there are some who go so far as to say it is not true at all. The belief is not rare that an oil that will successfully promote flotation concentration on any particular ore can be used in making flotation concentrates on another ore, if the other conditions are so varied as to make them applicable.

Of course it is not intended to make the statement that all oils will produce satisfactory flotation froths, for it is well known that some oils produce good froths while others do not, but the point desired to be brought out is that an oil that makes a good froth in one case will produce froth in another case if the proper conditions are provided; that is, as to the nature of the pulp, solution and combination of the two. The conditions of oil quantity and the presence or absence of a high degree of agitation must also be properly arranged to suit each case.

The Purpose of Oil in Flotation

The function of oil in flotation is a point that has not yet been definitely settled. The primary function, which has been clear since the inception of the flotation process, is that the oil serves to reduce the surface tension of water and thus provide for bubbles and froth of more lasting character than could be formed without its use. In practice some operators have brought out the theory that only with the lasting bubble in the froth can the best results in flotation be obtained. If that, however, is the only use of oil, what shall we say about those surface-tension and gas-bubble processes in which no oil is used, such as the Macquiston process, the Wood process and the others of like nature? In these cases flotation is successfully accomplished without the use of any oil whatever On the other hand, the flotation processes that are used on the largest scale and the ones that are achieving the greatest success are those in which oil is used. It seems evident, therefore, that in addition to the function of reducing surface tension, which the oil undoubtedly does accomplish, there must be further work that it performs. One of the properties of oils, it may be pointed out, is their preferential adhesion to mineral rather than to gangue particles. This is a fact that has been emphasized by a large number of experimenters and one that has been accepted as true up to a comparatively recent time. Now there are many who believe that there is no selective action whatever and that the difference in action of the oiled minerals and gangue particles is due to other forces altogether. In spite of this suspicious attitude, however, it seems almost certain that there is a certain preferential action, the oil adhering to mineral particles, particularly of a certain kind, rather than to the siliceous gangue particles of an ore.

Preferential Oiling of Mineral Particles

A careful examination of a pulp containing oil that has been added for flotation purposes will show that the majority of the mineral particles are more or less oiled, while the great majority of the gangue particles do not carry oil. This is subject to some qualification, however, for oils of certain classes—vegetable frothing oils, for example—are often found in the gangue and not in the mineral concentrates. Such condition is probably due to the solubility of these oils in water, since they are not to be found directly in contact with gangue particles, but in the pulp tailings. This subject will be treated in further detail later. Whether this adherence is due to preferential action between oils and mineral, one cannot at the present time definitely say, but the fact remains nevertheless. As to why the oil tends to prefer the sulphide particles, we know practically nothing. The reason probably depends upon the fundamentals of adhesion, which is one of the few forces of nature upon which extremely little light has been thrown so far by scientists. As a matter of fact, there are only a very few persons who know much about adhesion, while to the majority of even the scientists the cause of it is as unknown as, for instance, gravitation. We can certainly say nothing about the oiling of mineral particles that will throw any light upon the preference, if such exists, for the oil to coat the mineral particles rather than the gangue particles.

It is a well-known fact that there are surface forces that may change completely the tendency of bodies to act in any particular manner. If we assume it to be a basic fact that mineral particles do become oiled in preference to siliceous gangue particles, it is not so difficult to imagine that there would be a tendency between the oiled mineral particles and the gas bubbles to remain in contact with one another, the buoyant tendency of the gas then tending to lift the mineral in the froth. The well-known fact that solid particles carry electric charges, and that these charges in the mineral and gangue particles are or may be of different kinds, should be borne in mind in the elaboration of any theory of flotation or the function of oils in the process. The additional fact that these particles with electric charges migrate in the electric field, their direction varying according to the charge they carry, must also be remembered and may serve as a hint toward the official preferential separation of minerals and gangue. In an ordinary dilute pulp this migration may be found to account for the fact that the minerals become more or less separated from the gangue, and may

also help to explain why the minerals will take an oil film more easily and promptly, even if not to the entire exclusion of the gangue particles.

An objection to the electric basis for a theory of this kind, however, is found in the statement by authorities on colloids that this difference in electrostatic charge is a property of colloids only and does not apply to particles of practical size in suspension. Such particles, say these authorities, all carry charges of the same kind, and there would therefore be no tendency toward separation unless the oil film on mineral particles tends to change the character of the charge or to insulate the particle.

The surface films on particles will also have an important effect upon results. Surface films may be of four kinds—solid, liquid, gaseous or electric. In solid surface films we have as an example the limonite coating formed on various mineral particles—for instance, bornite—which more or less effectually prevents it from being successfully separated by flotation. It may be noted that if this surface film is changed or removed, flotation of the particles may take place. This is accomplished in practice by using an acid solution, or electrolyte, which removes the oxide, thus enabling the particles to be floated. The removal of this solid film may permit the oil film to be formed on the particles, which may account for its ready flotation under the changed conditions.

The Functions of the Oil Film

Thus we see that there are at least two functions of the oil: First, to reduce the surface tension of the liquid so that a more permanent gas bubble may be formed and, second, to preferentially oil the mineral particles so that some other effects, yet to be discussed, may be permitted to take place. The fact that the introduction of certain substances into the pulp solution may entirely change the effect of an oil is significant. Oils that produce a perfect froth under normal conditions may be so influenced that they will not produce a froth at all if certain substances are introduced into the solution. It may be noted that all of these substances are deflocculating agents—that is, such substances as will permit the oil to become emulsified and maintain itself in that condition. While it may still retain the property of reducing the surface tension of the water through solubility or miscibility, and may permit the formation of bubbles (although this is not usually the case), the emulsified oil is still in such condition that it apparently cannot effectively oil the mineral particles, so that its function will not be sufficiently well performed to enable it to be of use in promoting a flotation concentration, as has been noted by Van Arsdale.

As to the service performed by the oil film on a mineral particle, reference to recent discussion on the theory of flotation indicates that a prime requisite for the flotation of a particle is the presence of a surface film having the property of refusing to be wet by water. The oil increases this property. The surface-tension theory of flotation necessitates the presence of this non-wet surface.

To provide a non-wet surface on the mineral particle, the oil used to supply the film must be such that it will not be wet by water, or some constituent must be added to the water that will prevent it from wetting the oil. Many oils will not be wet by water, but some of them will, and the latter are not suitable for use in flotation unless something be added to the water to prevent the wetting action. Some acids supply this quality. If we attempt to explain the quality of an oil to be wet, or not, by water, we come again to the insurmountable barrier of adhesion phenomena, which alone can explain that quality.

It is to be remembered, however, that in spite of all this talk about oils and their effect, they are not the only materials that can form a non-wet film on solids. There are some solids that will do it; perhaps some gases, and not impossibly, electric surface charges. It has been shown that colloidal films of some kinds may be so manipulated as to produce this result.

Oils in general then, may be divided into two groups, the first containing those oils whose duty it is to provide the non-wet film on the surface of the particle; and frothing oils, which serve to make the froth possible by reducing the surface tension by water.

Coal Tar as an Auxiliary in Flotation

It is unfortunate but true that at the present time the realization of the functions that oils have to perform does not give us any advance information as to what kinds will be suitable to certain ores. So far it is altogether a matter of practice, the old rule of cut-and-fit being the only one from which much practical information can be derived. Every flotation plant finds an oil particularly suited to the ore being treated if the experiments are carried far enough. There seems to be no one oil that will give equally satisfactory results in every case. Coal tar may, however, become a universal oil when employed as a base for making good working mixtures of oils.[1] Until the latter part of 1914 the principal oils utilized for flotation in this country for copper ores were wood-distillation products and cresol. The price of cresol, about 30c. per gal., has made its use costly, even though as little as two pounds of it per ton of ore is required, as compared with coal tar, which costs only about 5c. per gal. Later, other coal-tar products less expensive than cresol came into use, and finally coal tar itself aided by some frothing agent, such as pine oil. Pine oil, however, is also quite expensive, and subsequent experiments show that coal tar with from 10 to 25% creosote gave equally good results. Until these experiments had been performed, coal tar was not considered as a flotation agent in this country, nor was it ever experimented with here, although it had been mentioned in some English patents. The experiments referred to led to its adoption in one large mill, and many others are now experimenting with it and getting good results.

There is considerable difference in the behavior of different tars, and it might be said that while classed as coal tar, the usual run of this material is really gas tar, or tar resulting from the manufacture of gas from coal. These oils are byproducts and naturally can be bought cheaply. A number of experiments have been carried out using this oil as a basis on ore of a porphyritic nature carrying about 1.6% copper, mostly chalcocite, with some chalcopyrite and about 0.15% oxide. Coal tar does not froth very well, producing a lean froth, although one of good quality. Pine oil is employed in combination with the coal tar, the pine product being a good frother and the combination of the two producing a carrying froth that gives good results in concentration. A mixture of 80% coal tar and 20% pine oil produces first-class concentrates. The price of pine oil, however, is high, and its use should be avoided whenever possible. The coal-tar

[1] "Use of Coal Tar in Flotation," William A. Mueller, "Eng. and Min. Journ.," Oct. 9, 1915.

products—cresol, creosote, etc.—which formerly served alone, are now mixed with the coal tar in proportions up to about 20%. The mixture thus obtained is excellent in both the pneumatic and agitation types of machines.

When coal tar is used long enough, it alone gives low-grade tailings together with high-grade concentrates. It requires, however, that the ore be held in agitation such an inordinately long time that the practice is not considered satisfactory, and it is usually better to add some frothing oil along with it to produce the results in a shorter time. Some tars may not give any results at all when used alone, but as soon as a very little of such an oil as pine oil is added, good results are often obtained immediately. The amount of oil will vary according to the ore, grade of concentrates and tailings desired; 0.005% of it will work a marvelous change in its effect upon some ores.

As the amount of tar increases in proportion to pine oil, the amount of concentrates increases and the mineral content of the tailings decreases. This may be on account of the proportion that coal tar bears to the mixture, or it may be because of the amount of oil resulting from increasing the amount of coal tar. Rough experiments seem to indicate that it depends upon the amount of mixture employed.

In a description of flotation tests on ores from Bisbee and Cobalt, Herbert J. French makes some interesting observations on oils.[2] In experiments on Bisbee ores the character of the material is described as porphyritic, the copper existing almost wholly as cupriferous pyrite, chalcocite and malachite. The total copper amounted to 6.04%. After testing the ore in the slide machine, the tailings were analyzed for sulphur, whence the percentage of extraction of the sulphides could be computed.

Tests on Various Kinds of Oils

Several oils, such as fish, sperm, whale, corn, cylinder, pine, pine-tar, lard and cottonseed oils, were tried under fixed conditions. Both qualitative tests, by shaking oil, acid, ore and water in test tubes, and quantitative tests on the slide machine were made. Of those oils available it was found that pine-tar oil gave the maximum extraction with the minimum weight of froth. Pine oil and fish oil both gave good results, but the froth, in addition to being of nonselective character, did not seem so lasting with either of these as that given by pine-tar oil. The character of the froth obtained by the other oils mentioned did not seem to indicate successful operation; hence the pine-tar oil was selected as the most desirable. In the experiment carried out at room-temperature on 100 grams of ore, the pulp containing sulphuric acid, with a 3-min. period of agitation, it was found that the extraction increased with the weight of oil added. A certain point, however, is reached beyond which more oil does not increase the extraction sufficiently to warrant its use in larger amounts. It is also evident that with the increase of oil, other conditions being the same, more of the gangue floats. In other words, the action of the oil becomes nonselective with increase above a certain point.

In another experiment, varying the acid, it was again found that there is a point beyond which further addition of acid is useless. When time is taken as a factor for variation, it is found that the longer agitation is continued the better the results. And again, when the temperature is the factor to be varied, it is found that from 50° to 65° C. gave as good extraction as could be had.

Experiments were then made upon ores from the Coniagas Mining Co., Cobalt, Ont. This ore contains about 13 oz. of silver per ton, mainly in the form of pyrargyrite, proustite, argentite, dyscrasite and native silver. The procedure was about the same as for the Bisbee ore, but in this case the tailings were analyzed for silver. In the first test, which was made with different kinds of oil, pine-tar, fish, sperm, corn, whale, cylinder, rape-seed, lard and cottonseed oils were tried, and it was clearly demonstrated that pine-tar oil was far superior to the others. Rape-seed oil gave a comparatively good extraction, but it was noticed that the froth was not so lasting as that produced by the pine-tar oil. The amount of oil was next varied, and in this case there was a recurrence of the phenomena of critical quantity. It was shown that beyond 2½ grams per 100 grams of ore, no benefits were derived from additional oil.

Examples of the Use of Mixed Oils

At the Gold King mine, at Gladstone, San Juan County, Colo.,[3] a low-grade silver-lead ore is treated by flotation, the oils used being carbolic and creosote. Carbolic oil is fed to the pump used to hoist the pulp to the stock tank, while creosote oil is fed to the first compartment of the agitator and pine oil is fed to the fourth compartment of the agitator, 300 c.c. of total oil per ton of pulp being used. In this case no acid is found necessary.

At a flotation mill in Mexico,[4] the best flotation agents among those tested were pine oils, a low-grade giving as good results as the better varieties. The F. S. pine oil of the General Naval Stores Co., which costs 26c. per gal. f.o.b. factory, has given exceptionally good results. For the best work in flotation it was necessary to have this oil present to the extent of 0.6 lb. per ton of ore. In actual plant practice, where the water is returned again and again to the top of the mill, the consumption of oil would reach about ¼ lb. per ton of ore. Pine-tar oil is much cheaper. It gives good extraction, but the grade of concentrates are low. Cresylic acid, when used with pine oils, increases the extraction about ¼ oz. of silver per ton. This hardly pays for its use. It may be said in connection with cresylic acid, however, that aside from any function it may have in assisting the actual formation of froth, it has the property of reducing the adhesion between oils that would ordinarily be wetted by water, and the water itself. Therefore the function of cresylic acid in the flotation process would seem to be in its quality of robbing water of the ability to wet certain oils.

It may be noted that so far in the review of the oils used coal tars have proved themselves to be poor frothers, and to get a sufficient volume of froth to make good recovery it is necessary to add something else as a frothing agent. Pine-tar oil, pine oil, creosote, etc., are the ones usually required. At the Inspiration mill, in Arizona, the flotation mixture is 80% crude coal tar, 15% light oil or creosote and 5% pine oil. At the Daly-Judge, a mixture containing 40% crude coal tar, 40% creosote and 20% pine oil is used. In the Coeur d'Alene country, wood creosote is used on zinc ores, and on some copper

[2] "Colorado School of Mines Quarterly," November, 1914.

[3] "Eng. and Min. Journ.," Oct. 16, 1915.

[4] "Flotation in a Mexican Mill," "Min. and Sci. Press," July 24, 1915.

ores plain turpentine will work, but pine oil is better. The latter seems to have the property of making a brittle froth that does not seem to last long on reaching the surface of the floating machine, an advantage in many cases. Creosote and light oil makes an elastic envelope that will expand to great size before bursting. The pine-oil bubbles will rarely be over ¼ to ½ in. in diameter. Castor oil, olive oil, oleic acid, palm oil, sperm oil and other oils of a lubricating nature have in general been replaced by oils more or less soluble or miscible in water, such as turpentine, pine oil, eucalyptus oil and all other coal- and wood-tar distillations. Extremely volatile oils, such as naphtha, gasoline, ether and alcohol, do not, apparently, have any effect themselves aside from the property they have of dissolving oils and thus making them more soluble or miscible in water.

On some of the mixed lead-zinc ores of the Coeur d'Alene country a mixture of three parts pine oil and one part creosote seems to work very well. The quantity used is about 0.5 to 0.7 lb. per ton. At the Silver Peak mill, Yerranderie, N. S. W., Australia, the best flotation results were obtained by the use of two oils. *Eucalyptus amygdalina* was used as a frothing agent and a dark lubricating-oil mixture as a carrier.[5] The pulp was heated to 120° F., at which best results were secured. The consumption of eucalyptus oil was ¾ to 1½ lb. per ton, and of the mineral-oil mixture 2 to 2½ lb. per ton.

The Qualities of Pine Oils

In discussing flotation oils up to this point it will be noticed that there have been references to products from pine distillation, sometimes called pine oils and sometimes referred to as pine-tar oils. It might be assumed at first hand that this was simply two different ways of speaking of the same thing, but such is not the case, because the products are different. Pine oil is produced by the steam treatment of pine wood, cut up into small pieces, while pine-tar oil is obtained through the destructive dry-heat treatment of the wood. According to the specifications of the United States Navy Department, pine oil is defined as "a properly prepared light, straw-colored oil, produced by redistillation of heavy, high-boiling-point fractions, resulting from the steam distillation of wood turpentine, and having a strong aromatic odor resembling turpentine." This oil should have a specific gravity of not less than 0.930 or more than 0.0945 at 60° F., and upon distillation should show at least 75% distilling between 200° and 220° C. The same authority, defining pine-tar oil, says: "A properly prepared distillate from straight pine tar, which latter has been obtained by destructive distillation of pine wood." It will be clear, then, that the two products are different and are not necessarily interchangeable in use where experiments have been made upon only one.

Some tests have been made on pine oils, in one of which the oil was noted as orange in color and having a specific gravity of 0.945. In this experiment 2 lb. of the oil was used per ton, and 2 lb. of acid was added to the pulp and agitated one minute before the oil was added. It was found that by using the oil thus, a good product was obtained, but by making two or more operations on the same pulp, adding 1 lb. of the pine oil first and then at the second operation a pound of oleic acid, a high-grade product was also produced. In testing two or three kinds of pine oil in combination with oleic and other oils, it was found that a consistently good product was obtained each time, and that the percentage of extraction increased with the number of operations that were performed on the pulp, up to the point where practically all the sulphide had been removed from the oil.

In describing the flotation process at the Oneida Stag mill, at Idaho Springs, Colo., R. W. Smith[1] points out that oil at the rate of 2½ lb. per ton of dry feed was added. The oil cost was materially reduced by mixing three different kinds—in this case consisting of one part of mixed crude wood tar, fairly cheap; one part of spirits of turpentine, more expensive; and four parts of a cheap, local mineral oil. The mineral oil constitutes a cheap base for carrying the other oils. It is not always possible to find a mixture that will give a clean, high recovery and at the same time make clean products. By mixing in this way, however, the cost per gallon for oil on the ground was reduced from 45c. to 23c. This reduces the cost of oil per ton of crude mill feed from 6c. to 3c.

Oils Used at the Anaconda Mill

In the description of flotation at Anaconda, the kind of oil used for their flotation has been noted by Laist and Wiggin[2]. A product that has heretofore been little used in flotation, but has been the subject of some experimentation, is a sludge-acid kerosene that has been employed by Minerals Separation and is called M.S. 37. It was used practically all through the experimental work at Anaconda and gave highly satisfactory results. Although exposed to the weather in iron drums during the winter months, it gave no trouble by becoming too viscous. One barrel of oil from the Western Oil Co. was tested during February, but did not give as satisfactory results as the oils from Standard Oil Co. and the Union Oil Co. of San Francisco. One barrel of oil from the Midwest Refining Co. was tested during February, but did not give the results obtained on the other two. From the Producers Refining Co. came an oil that could not be tested, as it had solidified in the barrels and did not become liquid after standing for days at a temperature of 60° F. or better.

During the experimental work creosote oils were tested with varying results. The creosote from the Cleveland Cliffs Iron Co., of Marquette, Mich., is obtained as a by-product in the manufacture of charcoal from hard pine. This is known as M.S. No. 33, the number given to it by the Minerals Separation Co. It was used practically throughout the entire work with highly satisfactory results. Creosote from Pensacola Tar and Turpentine Co., of Gull Point, Fla., was used in considerable quantity in experimental work. It gave fully as good results as the Cleveland Cliffs creosote. It is made from Georgia pine and is known as No. 400 by the Pensacola company. A barrel of creosote from the Crichton Pine Products Co., of Alabama, was tested and gave good results. A test was made using a barrel of tar creosote from the Butte Gas Works, and this gave fairly good results. The test was too short to be conclusive, but it was thought that the tar creosote would give satisfactory results.

In testing the Callow machines a mixture of oil containing tar creosote from the Barrett Manufacturing Co. was used with good results. In the laboratory experi-

[5]H. Hardy Smith, "Eng. and Min. Journ.," Dec. 11, 1915.

[1]"Flotation Replaces Cyanide," "Eng. and Min. Journ.," Jan. 15, 1916.

[2]Bulletin A. I. M. E., March, 1916.

ments it was found that tar creosote gives good results. Creosote from the timber-treating plants at Rocker comes from the J. F. Lewis Co., of Moline, Ill. It did not give good results, although the test was too short to be absolutely conclusive.

The Acid-Hydrocarbon Products

The reference to the sludge-acid kerosene introduces a new oil, or hydrocarbon product, that has not been spoken of before, the manufacture and production of which is not well known by flotation men. The product is one from the distillation of petroleum. The burning-oil stocks from the steam stills, consisting of from 65 to 75% of the crude oil charged, are treated at the rate of 5 to 10 lb. of 66° commercial sulphuric acid per bbl., in order to improve the color and odor and also to remove decomposition products which cause the flame to smoke when burned in lamps. The process is performed in agitators, using an air-blast for agitation. In order to get the full benefit of the acid, any water present must first be drawn off and a small amount of acid added in order to remove all the remaining water. This is agitated for from 20 to 40 min., allowed to settle from the oil and then drawn off. The remaining acid is then added and the mass agitated for from one-half to one hour, allowed to settle from 3 to 5 hr., and drawn off. The acid treatment removes the tarry matter formed during distillation, also a large percentage of the unsaturated hydrocarbons and sulphur compound. The acid is turned almost black after treatment, and is known as sludge acid. It is allowed to settle from the oil and is then drawn off into tanks and delivered to the acid-separating plant for the recovery of the acid. This sludge acid is the product that has been found useful in flotation. It will be observed that it comes from the treatment of light burning oils. A similar process is practiced upon the lubricating oils, but the sludge acid from these heavier oils is black, asphaltic in nature, and very viscous—almost a solid mass. It, with the sludge from the burning oils, is sometimes agitated with water in a lead-lined separator, the weak acid recovered is concentrated in lead pans, and finally in stills of cast iron to 66° Baumé, and then used over again. The residue from this treatment is usually used for fuel or worked up into pitch. It will be seen that the use of these sludge-acid oils may possibly combine the features of having the oils necessary for reducing surface tension together with the acid required in the treatment of some particular ores.

In a test made on some oleic and coal-tar oils, a cycle of four different operations was carried out on each. The test was performed at a dilution of 4:1 and at a temperature of 45° C., the ore being a typical blende combination with heads averaging 15½% Zn. The additions consisted of the oleic oil and 2 lb. of acid per ton. Clean concentrates of 45.6% zinc were produced, with clean tailings containing 1.3% zinc. In using the straight coal-tar oil the same feed produced clean concentrates of 49.5% and clean tailings of 1.2% zinc. In each case there were four operations performed.

There are several different kinds of pine oils, made by different manufacturers, and although the qualities are in general approximately the same, some difference may be found in particular products. Taking for example Spiritine and the Atlantic as two different examples of pine oils, it has been found that they both give good froth. It may be noted that when pine-tar oil is used, a long contact with an acid solution will be likely to cause the froth to break up and the concentrates to drop out of it. For this reason, where long contact is essential it is believed, at least in some cases, better to take an oil in which the pine-tar product does not exist. One of the two pine oils has been found to contain pine tar, and although it gives an excellent froth on short agitation, long contact with acid will, as has been said, cause the concentrates to drop out of the froth. Where acid is not used, however, pine-tar oils are particularly advantageous and make splendid froths.

A large number of tests have been made with acid petroleum products, some of which make good flotation oils. In tests on Texas crude oils, most of them have been found to give good results in combination with a frothing oil. The frothing oils used in combination in this case were oleic, stearic, pine and pine-tar oils. The Texas crudes are usually known as A, B, C, D, E and F. Combinations containing half of these Texas oils and half of one of those that have been mentioned as frothing agents were tried, and most of them gave very good results. The Texas crude "A," in proportion of one-half to one-half of stearic, however, requires considerable agitation. This agitation is more than is required when the other combinations of oils are used. The combination of the Texas crude "C" with oleic acid, in the proportion of half and half, froths pretty well, but the froth did not show much strength nor stand up well.

The Minerals Separation oils have already been referred to, but in some cases they are used in combination with pine and pine-tar oils, as well as with oleic and stearic acids. In a few cases, however, tests of a mixture with oleic and stearic acids did not give good results, but there was probably some local reason for such an outcome.

Other Oils Tested

Thorough tests have also been made of such products as crude oil, fish oil and many others. Fish oil gives good results, and a combination of fish oil and oleic acid does too, although it shows some tendency to carry up siliceous matter with the mineral. Fish oil and pine oil in combination do not seem to do any good at all. In the experiments made on this combination, no results were secured. Stearic and oleic acids give good results, as also does stearic acid alone. Beaumont oil with tar oil and with oleic gives fairly good results, and some paint oils may also be successfully used. Coal-tar oils have already been mentioned, as has also their combination with pine oil and other frothing agents.

Pine oils and pine-tar oils have been tried in combination with cottonseed, lard, nitrobenzol, turpentine, oleic acid, stearic acid, corn oil and other hydrocarbons. The results seem to vary with the kind of ores treated. In many cases a good result can be obtained with blende ores, while the same oil combination will not work at all on copper. At the same time, if the oil mixture is changed and also its proportion to the dry ore itself, the same oils, alone and in combination, may be made to do good work on the copper ores. The same applies to the treatment of any other kind of ore where changes in oils seem to give different results. In spite of the efforts that have been made to discover some rule for the application of various oils to different kinds of ores

and in spite of the careful study given to the matter, no general principles can be announced. At many times the experimenters have seemed to be on the track of a logical explanation, but with the formulation of rules, numerous variations and objections to it have cropped up, so that at the present time there is really nothing that can be laid down as specific.

Tests have been made on corn oils, and the corn oil in combination with pine, pine-tar, oleic and stearic acids has been tried. All of them give good results under some circumstances and poor results under others. It might be said in general that any oil will form a good flotation product if the proper combination with its complementary oil is used. By this is meant that if a carrying oil is used, it must be supplemented by a small quantity of a frothing oil. The frothing oils and the carrying oils are complementary to each other, one supplying the qualities that the other does not possess. There are some oils that combine the qualities of carrying and frothing agents, but as a rule they are so expensive that they cannot be used alone, and it is found cheaper to use a large quantity, comparatively speaking, of the cheaper carrying oil and a much smaller quantity of the more expensive frothing agents. Of the Texas crude oils there seems to be none so far tested that can be depended upon to give satisfactory results alone. They all have an asphalt base and bring forth a light, rich, unstable froth. In combination with either pine, oleic or pine-tar oils, they give good results. They are graded according to their specific gravity, the lightest oil being the Texas "A" and the heaviest the Texas "F." The latter, in combination with oleic and pine in a proportion of one-third each, gave remarkable results on some careful experiments.

Comparison of many different kinds of pine oils show that there is very little difference in the product of different manufacturers, most of them having about the same properties. Oleic oils have been tested in combination with corn, pine-tar, turpentine and other oils, and also straight. In proper quantities they seem to give good results in every case. Oleic oils of different manufacturers have been also compared, and there seems to be very little choice between them.

Miscellaneous Oils Tested

Tests on a lot of miscellaneous oils have given, in general, good results, although some will not work when economically possible quantities are used. Wood creosote works well and produces a good, thick froth, but has a tendency to carry silica into the froth. Spike oil was tried, but it usually does not seem to produce a froth that is tough enough for practical satisfaction. Rape oil produces a pretty good froth, fairly clean, although on continuous subsequent operations there appears to be a peculiar scum that interferes with satisfactory flotation. Nitrobenzol is too light for flotation, and no results can be had with it. Castor oil alone does not usually produce good results. In combination with turpentine it will work satisfactorily, but such large quantities of it have to be used (up to 8 or 10 lb. per ton) that it is not economically practicable. Cottonseed oil and coal oil (kerosene) alone did not produce any practical results. Coal oil and pine-tar produce pretty good results, but require a large quantity of the oil in proportion to the tonnage treated. Turpentine alone does not produce satisfactory results, according to experiments, nor does the variation called turpentine oil. All the turpentines work fairly well, however, when combined with a heavy oil. The use of fish oil in large quantities gives fairly good results, but its extremely disagreeable odor would be a drawback. The trouble experienced when stearic acid is used alone seems to be that stearic brings the congealing point down, and this oil also takes more heat to render it liquid enough for use. It seems probable that coal-tar oils and coal tars themselves will probably be the most generally useful oils in flotation processes, being used as carrying oils and forming the bulk of the oils added. They must, however, be combined with some oil having frothing qualities, such as pine, pine-tar or many of the other lighter oils already mentioned.

The peculiar result of a large number of oils tested seems to be that the only way to determine whether an oil is applicable for flotation of a certain kind of ore, is to try it on that ore. And, it will be noted, it is advisable to try an increasing number of oil combinations and quantities. Since, as has been mentioned, it is totally impossible to outline any rule for forecasting the results to be given by oils of certain classes on ores of particular kinds, a large number of experiments is absolutely necessary to accurately determine such oil or combination of oils that can be used, and the minimum quantity that can be used to secure the greatest economical quantity of flotation concentrates.

Testing Flotation Oils

Oils may be tested for their use in flotation plants and, in fact, no oil should be used until a thorough test has been made and its value for use in the plant proven. The great difficulty is that there is no standard way of making tests that will indicate the usefulness of an oil in flotation, so that the usual method is to choose a standard ore on which tests of all kinds are run and recorded, the effect of the oils being referred to this particular ore as a standard. This method has been brought out by J. Coutts.[3] He points out that the first thing to do with an oil is to measure its density for future calculation, as it will be measured by volume in the laboratory and there must be some method of transferring these volume units into weights.

Coutts classifies three different kinds of standard tests: First, one for mixed sulphides; second, one for differential separation; and third, one for the flotation of copper and iron sulphides. He believes that oils high in phlanderene are best for differential separation of zinc-lead sulphide ores. Phlanderene is an oily constituent that leaves a gummy residue on evaporation. It may be tested for by evaporating oils at moderate temperature and examining the residue, or it may be detected by the polariscope. An oil giving a deflection by the polariscope of 60 or over is considered to have a sufficient quantity of phlanderene for use in copper flotation.

For testing the number of drops of oil in each cubic centimeter a small burette is recommended, the discharge orifice of which has been made smaller by heating and dumping it up. About 80 or 90 drops per cubic centimeter should be given at normal temperatures. The number of pounds of oil per ton of ore can be found, when the specific gravity and number of drops in one

[3] "Aust. Min. Standard," Apr. 8, 1913. Reprinted in "Eng. and Min. Journ.," June 19, 1915.

cubic centimeter are known, from the accompanying formula:

$$\frac{2{,}240 \times sp.gr.}{453.6 \times drops\ per\ c.c.} = lb.\ of\ oil\ per\ ton$$

The great difficulty in testing oils for flotation is that it is not yet known what quality it is that makes oils of value for flotation. The only way to find out if an oil will do for this purpose is to try it on the ore to be tested. Some laboratories have under way series of tests looking toward the determination of the flotation quality of oils, and also the matter of changing the quality so that they may be used for flotation successfully. In this case reference is not had to the mere mixing of oils to secure good flotation froth, but the actual changing of the quality of the oil itself by such means as dissolving different materials in it, sulphonating it, or modifying it by heat or other treatment. Some progress is being made on the production of oils of good quality from cheap oils that can be obtained readily in particular localities.

The Classification of Oils

The New York Produce Exchange defines crude petroleum as follows: "Crude petroleum shall be understood to be a pure, natural oil, neither steamed nor treated, free from water, sediment or other adulteration, of the gravity of 43° to 48° Bé."

Since the production of the lower Baumé gravity oils, the limitations in regard to gravity have been relaxed. In order to ascertain whether or not the petroleum conforms to the foregoing rule, it is usually distilled in 10% fractions, and the Baumé gravity determined on each fraction. It is obvious that from the complexity of crude petroleum each succeeding fraction would show a somewhat regular graduation in specific gravity, whereas in cases of adulteration it would be more or less irregular. There are a number of tests that can be performed on oil to determine its constituents in oils of different gravities and also to determine the quantity of sulphur contained, the specific gravity of the oil, the water contained, and other tests. Burning oils are usually tested to show their flashing point. Lubricating oils are also tested in the same way to show their flashpoint, and in addition, their viscosity and their cold test—that is the temperature at which they become solid. All of these are set forth in detail in the textbooks on the subject of oils and are too complicated to be treated here, particularly in view of the fact that they have no relation whatever to flotation so far as we know at the present time.

Aside from the petroleums there are many liquid fats and fatty oils in addition to the solid fats. In the first class there are the vegetable oils, which may be divided into drying, semidrying and nondrying. In the second class are the animal oils, which are subdivided into marine animal oils, such as fish oils, liver oils and blubber oils; and the terrestrial animal oils.

The solid fats are divided into vegetable fats and animal fats, and the latter are subdivided into drying fats and nondrying fats. In these classes come a host of different kinds of oils, many of which have already been mentioned in this article and hundreds of which have not. It seems that almost every vegetable or plant will produce an oil having some different qualities from every other. There are also animal oils and fats of different qualities and having different effects. Only a few of the large number are of interest in flotation, because only those few occur in such abundance as to be commercially cheap enough to be used in commercial process of this kind.

Chile Mills

The superintendent of the New Homestake Mining Co. and the manager of the machinery company that makes the Rex chilean mill, united in giving us permission to publish the letter of Peter Garnnet, mill foreman, which he sent to the Rex company as a testimonial. Peter's report is crude but unalloyed gold. It is not only amusing, but also there is a certain amount of technical information to be derived from it. The first letter was addressed to the manager of the Rex company. The testimonial follows:

Mr. Jarvis Dear Sir:

after havin obtande the results that I hav from the Rex Chilian Mill I have desided to Give the Publick a few facts about what they can do. if you so desire you may hav the inclosed article publeshed in the minen *Journal* or Magazien, in fact eny where you so desire. you may correct statments by leeven out or aden to eny thing for your best ensterst. as I havent told half that I coad truthfuly tell if so amine too. I can more than Bere out every statment Made. I hav Som Pictures of the Mills fit up with new Steel and also Steel worn out. also shoin weight of New Steel and weight of old steel also showin how menny tons it Ground in waring a way more than ninty persent of the Steel. If you deside to hav the inclosed article poot in print please Send me a Copy of the Same. also if you at eny time desire eny infermation about the Mills Let me no what it is and it will Bee forth Comen.

Very Respkful yourse

Peter Garnnet.

Malin-ad. Independence, Idaho, General Delivery.

P.S. you Mite Send me a Celender for Crismess if youre Company Deels in Such Mashenry.

To Hoom it May Consern Set up and take notis and Gett a few facts about Chilian Mills and what they can doo. in the first place will say that I hav ben in the Mill Bisness for twenty od yiears and in five different States Namley, Montana— Idaho— Utah— Nevada & Colorado and in late yiears hav handeled twlve diferent Makes and impraved Makes, and hav allways Suceeded where others fald. Let me say rite here that there is more in the operatin of a Chilian Mill than the partickler Make, for they are all bilt to doo the same work. at the Present time I am at the New Homestake operatin fore Chilian Mills of the Rex Make that I installed more than eighteen months a go. to be asack they strted to grind ore on the 14 of May and hav run Constent ever cins. at present they are Grinden more than one hundred tons per Mill for every twenty fore hours running time. Under stand this is the hardest and tufest Rock to grind that I ever seen. I am Grinden it to thirty Mesh. it is crushed to about one inch before it Getts to the Mills.

Will now giv you a few facts that I beg you to note very Closley. after more than eighteen months Constent running under the Most Severe test that I ever Saw a mill poot thrue this is the Condishen they are in to day.

We will take the Mullar Barings and the Penion Barings which is the most important barings of the Mill, is just as perfect as the day they first started. all Bushens is in perfect order. Penians and Geer wheel, dosent sho ane particle of ware so far. in fact the Mills is just as Good in every way as they was the first day they ever run. Lost time for repare sofar Nothen. Cost of repars out side of Steel nothen. a few miner Changes made at a very small Cost. time Changen a full sett of steel from too hours and twenty five minits to fore hours. on Corse I hav a very simple proses of Keyen the Dy ring in plase that will hold it in plase and never moove eaven if it is worn ploom in too. on Corse that enables us to start the mill the moment the Steel is replased which I hav don in as Loe a time as too hours and twenty five m. a nother very important thing is the Geer Bolts in any make of a Mill they are allways loos. I hav a gear bolt that can not Lusen under eny Cercumstanses. in fact it is the little things that must be don and don in time. and there will be no big things to doo. You would not think of haven a miner repar youre watch pervided it cost a few hundred Dollars. A Mill is a Grate eal harder to repar and Keep in repar and needs more atenshen than eny other mashenry mad. for to obtaine the best results everything must be kep Just in as perfect order as the best wach ever Made. A Criple Cant doo the work.

Now for the Steel it is very important to no when youre steel is in the Shape to Giv the best results. youre steel should be run so as to Keep the out side of the Di ring and also the out side of youre muler tires the leest bit the thenest at all times. by so doin you will Gett the best results. you Should at lest Gett ninty persent ware out of youre steel. also remember that on some ores it is nesary to tun youre mills at a faster speede than others. Dependen on the hardness of the ore. a nother Good thing to remember is to find out how fine to crush the ore before it Goes to the mill. as in many cases they make it too fine to Gett the best results from the mill. I feel saft in sayen that I can under ordenry circemstanses Grinde too hundred tons of ore to a thirty mesh in twenty fore hours with a Six foot Rex Mill and with all the Experence I hav had with Chilian Mills and to take every thing in Consideration the Rex Chilian Mill is fully fifty persent better than eny mill I ever handeled. Still there is a few Miner improvements that no dout will be over com in the nere fucher.

I hav ben thinken of ofern to Giv som Manafactuer Compney the rite to patent a few of my ides about Chilian Mills such as Keyen the Di ring in also a geer bolt that Can not get loos and severl other small But very important things. that will all aply to eny make of Chilian Mill to Just see how nere wee can Gett one to perfection. Will say in coluden that this is no payed for advertestment, it is simply facts as I hav found them and I will invite eny one that this may interest if they dout eny Statment made to visit me at the New Homestake and be convinst that every word here riten is the truth, or adress me at Independence Idaho and I will Gladly answer all Comuniations. Respkful yours PETER GARNNET.

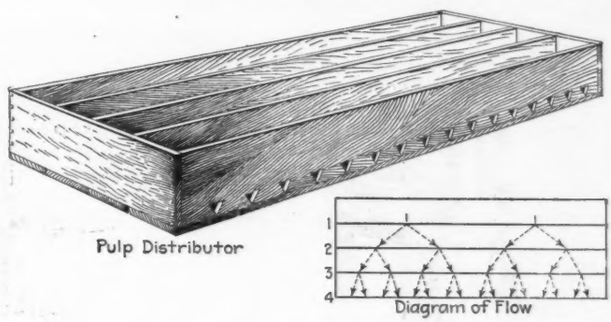
Tungsten Powder, in crystalline form obtained by the reduction of trioxide, if stirred into a solution of an alkali nitrite and heated at 127° for 3 or 4 hr., then thoroughly washed and dried, may, according to C. Trenzen, Brit., 14,381, June 15, 1914, be compressed into a bar, and consolidated by highly heating in vacuo or an inert gas. The product is stated to be ductile.

An Efficient Pulp Distributor

By ALEXANDER MCLAREN*

In plants where plate amalgamation is used for recovery of gold, it is important that the pulp be distributed evenly over the surface of the plates. With the splash from Chilean and Huntington mills this is not as easily accomplished as it is in the case of stamps. In amalgamating below such machines, I have used several forms of distributors, but have obtained by far the best results with the one shown in the accompanying sketch. It can be made in about two hours by anyone having any carpentering ability. For use at the head of the average-width plate the box will need to be 4 ft. long, 1 ft. wide and 4 in. deep, and made of 1-in. surfaced lumber.

Referring to the diagram, the partition marked 1 contains two triangular openings with the points down, the total area of the two openings being equal to the area of a 2-in. pipe. The next partition has 4 triangular openings the total area of which equals that of the preceding two. Partition 3 contains 8 triangular openings the total area



A GOOD PULP DISTRIBUTOR

of which is equal to the 4 in the preceding partition. Partition 4, the final discharge, contains 16 openings the total area equivalent to that of the 8 preceding ones.

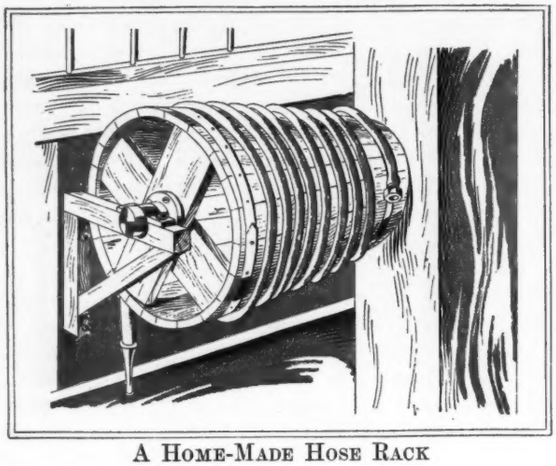
Each of the openings must be accurately spaced, so that the flow from it is evenly split and feeds two of the succeeding openings. If the mill pulp is delivered in the middle of the first partition, the box perfectly level lengthwise and tilted with the pitch of the plates, the tailings will "hutch" about each of the series of openings and an absolutely uniform flow will be obtained from each of the discharge openings. Round or square holes will not give the results obtainable from the triangular-shaped ones. I make no claim for the originality of this device, but have used it with success in a number of mills.

Cementation at Moonta

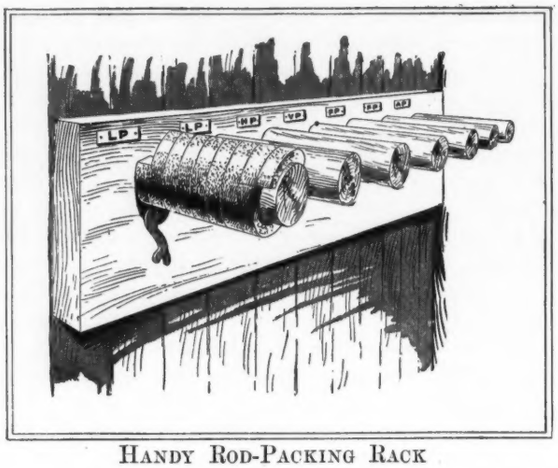
The satisfactory return of copper from the cementation process at the Moonta mines during the last four years is due principally to the provision for more expeditious treatment of the slime residues. Methods were introduced, according to the 1915 report of the Wallaroo & Moonta Mining and Smelting Co., Adelaide, South Australia, to accelerate the atmospheric oxidation. The whole of the slimes have been leached several times and the fine material must be given more rest. Without some plan to further increase oxidation the output from this source cannot be maintained and the production of cement copper will be more dependent on what can be secured from the tailings heaps.

*Northwestern Mining Co., Bearmouth, Mont.

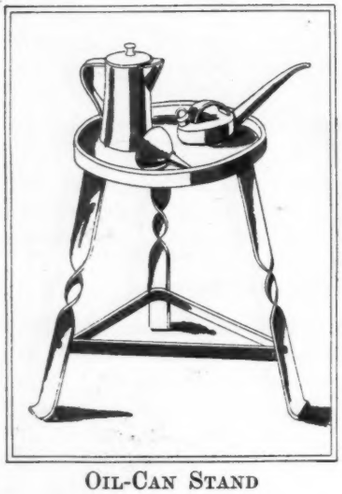
Handy Hints and Clever



A Home-Made Hose Rack

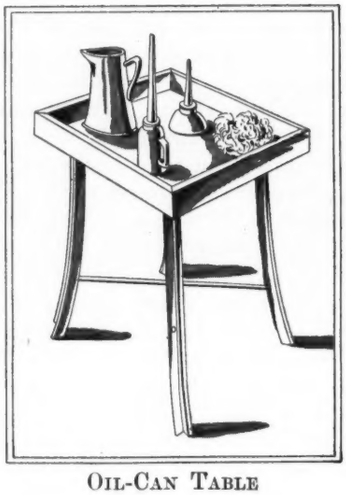


Handy Rod-Packing Rack

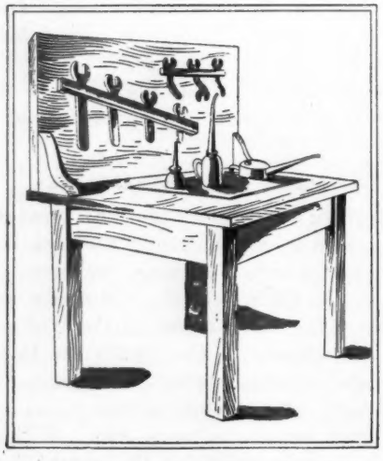


Oil-Can Stand

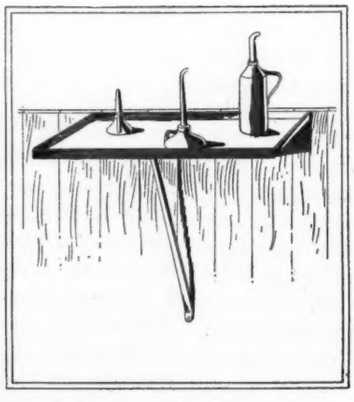
Portable Tool Stand



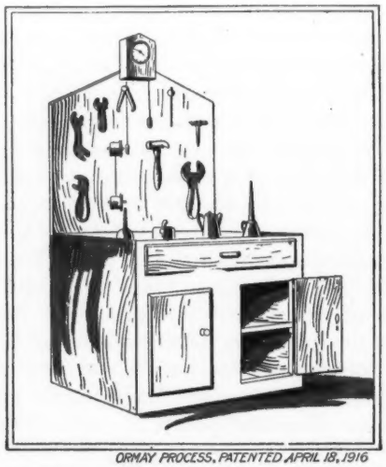
Oil-Can Table



Combination Table and Wrench Board



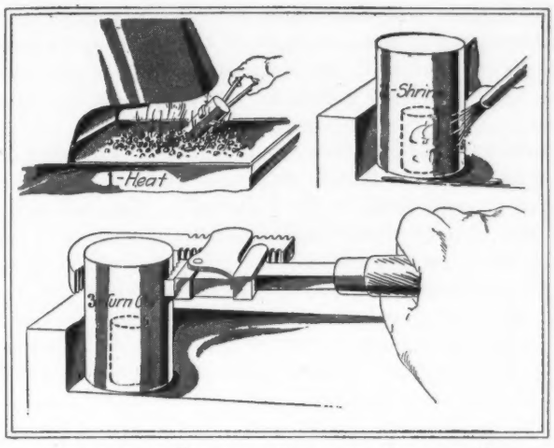
A Convenient Shelf for Oil Cans



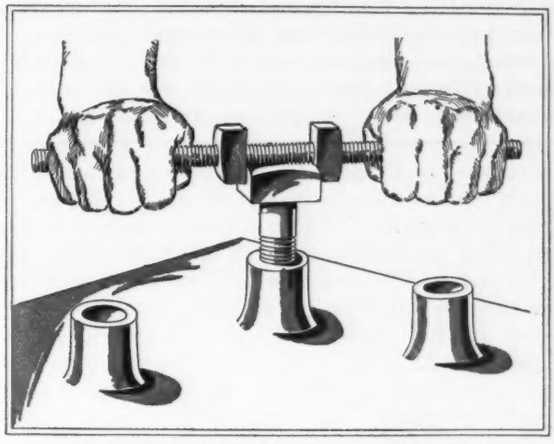
A Useful Engine-Room Cabinet

Engine-Room Furniture That is Easily Made

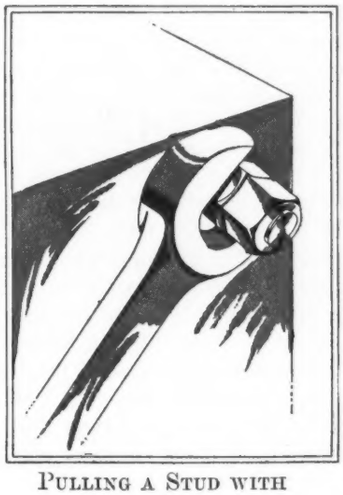
Kinks for the Power Plant



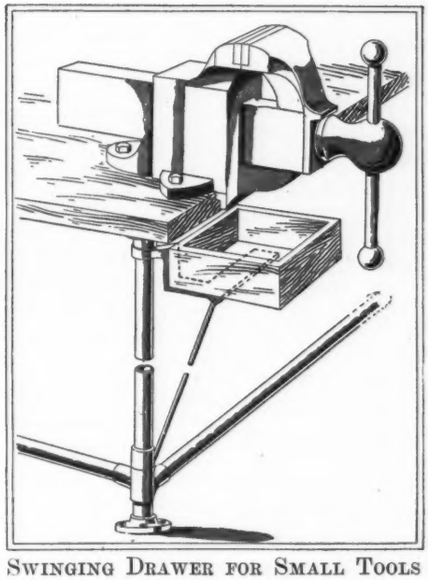
GETTING A GRIP ON TIGHTLY DRIVEN PIN



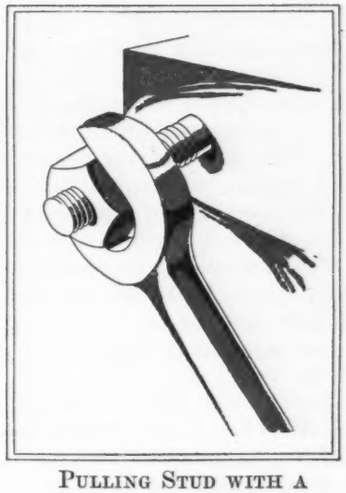
A QUICKLY MADE EMERGENCY WRENCH



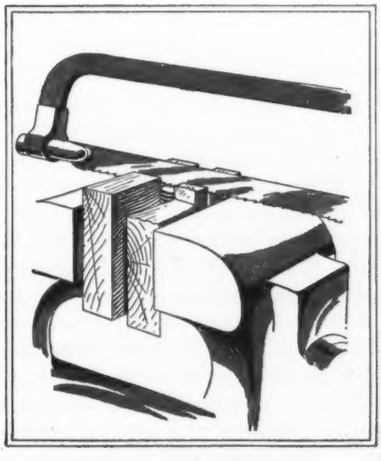
PULLING A STUD WITH LOCKNUTS



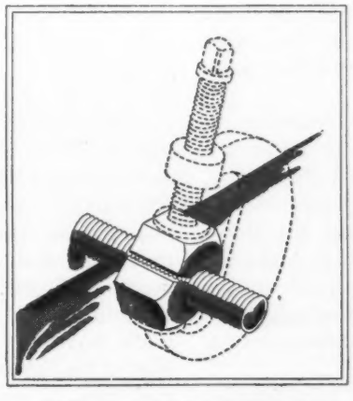
SWINGING DRAWER FOR SMALL TOOLS



PULLING STUD WITH A SHRUNK NUT



HOLDING A SCREW FOR SLOTTING



PULLING A STUD WITH A SPLIT NUT

WING NUT HELD BY SPLIT NUT

Some Stunts That Work Out in Practice

Crushing and Grinding Machinery

SYNOPSIS—Crushing and grinding machinery shows a steady development, with but few machines of new types. The tube mill is the only novel appliance of recent years. Types are discussed and advantages of steel compositions are mentioned.

The changes in recent years in crushing and grinding machinery have been less, perhaps, than in any other line of metallurgical machinery. This is not to say that new devices are not being continually invented and placed upon the market, but operators seem slow to adopt these machines, preferring to wait until each new idea has been thoroughly tested out and has proved its efficiency beyond all doubt. As a matter of fact, few of them have been able to demonstrate superiority in sufficient degree to make them universally acceptable. The only grinding machine that has become standard in recent years is the tube mill, and that has been adopted from the cement-making industry, which has used it successfully for a number of years.

Primary Breaking Appliances

Primary breaking machines are reasonably divided into two classes, the first including the machines of the Blake type and the second the breakers of the gyratory type. In former years a third machine was considered a type of primary breaking device, this being the Dodge type of crusher, but this has fallen from its former position, first into the class of secondary crushers and finally into disuse almost together, since other kinds of machines have seemed able to do its work cheaper. The Blake and gyratory types, then, remain preëminent in the field of preliminary breaking.

A great many mills make use of the gyratory machine as the primary crusher, using it in large sizes to break down boulders and large pieces of ore coming direct from the mine. The gyratory crusher has been for years considered best suited to work of the kind, and most of the mills constructed previous to the last four or five years have used it for primary breaking. Recently, however, opinion has tended the other way, and some of the new installations are using breakers of the Blake type to do the work that was formerly given to gyratories—breaking down large oversized boulders and pieces of ore coming direct from the mines. Blake breakers are now made to receive pieces as large as 48x90 in. In this way they can be made to take the largest pieces of ore that ordinarily come from the mines.

Possibly the reason why the Blake-type crushers are replacing gyratories for large work is that the latter is a much more complex piece of machinery and the cost of repairing it is considerably greater than in machines of the Blake type. Should it come about that the Blake breakers displace gyratories for preliminary breaking, it is possible that the latter will have no place in the modern mill. Stage crushing may be done through Blake breakers of various sizes, until the ore is reduced to such size as is applicable to roll crushing.

Secondary crushing may be done, as has been pointed out, by Blake breakers, or it may be performed in any one of several other kinds of machines. The Symons disk crusher is a new aspirant for honors in this field and has succeeded in making a permanent place for itself in many mills. Rolls may also perform this work, and there are various other machines that have been applied to it. Breakers of the hammer type or the chain-and-hammer type have been used, but their application is so limited that they cannot be called, as yet, a universally applied type.

Another machine that has been used for secondary breaking, and one that is coming into more general use at the present time, is the ball mill. The ball mill is not new, but is of a type that has been used for many years, the Krupp machine being possibly the best known. These machines have been made for a number of years and have been used in some industries, but in mining they have never become very popular. The Krupp machine is unpopular because of its complex construction and the fact that it carries screens inside the drum, these screens wearing out rapidly and being unhandy to renew. The ball mills that are the most popular at the present time are the Hardinge conical style and the ordinary drum ball mill made by various manufacturers. The Marcy mill comes under this heading, since it is of the ball type. It also carries screens for sorting the ground material. In the latter mill, however, pains have been taken to make removal and renewal of the screens easy and rapid. These efforts may be said to have been successful, and the mill is in use in several of the large, modern plants.

The Marcy ball mill is practically a tube mill with length less than its diameter and is also fitted with lifters. It uses heavy steel balls to accomplish the breaking. This machine contains two compartments—one the grinding drum proper, where the useful work is accomplished, and another smaller one, divided from the main part of the mill by a perforated diaphragm. This diaphragm allows ground material to pass through into the smaller chamber, in which the screens perform a further separating service, the oversize being returned to the grinding chamber of the mill and the undersize discharged. The object of the diaphragm is to allow all material to pass quickly through to the end of the mill, while lifters are inserted that expedite circulation and discharge and eliminate the restricted flow that occurs with the center-overflow discharge.

The Status of the Stamp Mill

As secondary crushing machines, probably the stamp is the best known of all, since it has been in use for many years and has been employed for all kinds of crushing, much of it being of a kind for which it was not at all fitted. The characteristics of stamps are so well known as to require no elaboration here, but it is noteworthy that, while it has been acknowledged to be less efficient than many other machines, it has qualities that have enabled it to withstand many years of competition and still hold a place for itself in metallurgy. As a result of the attack made upon it within the last 10 years, however, the stamp is gradually retiring and, except in special cases where ores are of a peculiar character that seem to require it, the stamp will probably be very little used in mills that are to be constructed in the future. In corroboration of this view it may be noted that the new mills in the Alaska low-grade gold fields are being largely equipped with rolls instead of stamps.

These mills propose to beneficiate a low-grade gold ore by concentration, and the breaking and crushing scheme is to pass the ore in stages through breakers and rolls. Even in gold mills in which ore of good grade is to be beneficiated, the stamp will probably be displaced except in those instances where mortar and plate amalgamation are to be the only methods of gold recovery. The Nissen stamp, a variation of the ordinary gravity stamp in which each stamp works in a separate mortar and has a very large comparative area of discharge, has been successful in some instances and is still being used with good results in a number of cases.

It is of interest to note that at the Dome mill, at Porcupine, Ont., ball mills are replacing stamps as breakers. These mills are of the Hardinge type, 8 ft. in diameter, the cylindrical part being 30 in. long. Six of these mills are to be installed and are to take 3-in. feed, reducing it to about 10 mesh.

The Development of Stage Crushing

Probably the most important development in ore crushing in recent years is the growth of the idea that no machine in existence is capable of crushing ore efficiently from large pieces to the fine meshes necessary in preparing most ores for treatment. The idea is being recognized that each machine has its most appropriate field and that it should not be called upon to do anything else. It is possible, of course, to put 2-in. ore into a stamp mill and reduce it at one operation to minus 40-mesh, but the work is not efficient and can be done more cheaply by using more appropriate machines. Modern metallurgists recognize the advantages of stage crushing, and the mills designed at the present time are arranged to take advantage of it. In this connection it is interesting to quote from an article by Philip Argall, in the *Journal* of May 11, 1904.

> Those of us who have investigated the mechanical efficiency of a given machine, meaning thereby the pounds of ore crushed per horsepower-hour from and to stated maximum sizes, know that each machine of value has its economic limit at which it will give the maximum output in pounds per horsepower-hour, and also that there are fixed ratios of reduction that should not be exceeded. These limits, however, are not in every case determined, yet I have no hesitation in stating that the machine which reduces a 2-in. cube to pass a $^1/_{50}$-in. screen aperture in one operation is a very inefficient apparatus, even if it should prove to be the most modern 1,350-lb. stamp.
>
> I have elsewhere shown that the efficiency of a rock breaker falls off rapidly when a reduction exceeding 4 to 1 is attempted, say 8-in. to 2-in. cubes, and that the same rule holds good for rolls; and that for reducing ores below 2 in., rolls are vastly superior to rock breakers, for the reason that, while both machines work practically on the same principle, one is an unbalanced or imperfectly balanced intermittent-action reciprocating machine, and the other a perfectly balanced continuous-action rotary machine. Large rolls could be constructed that would compete favorably with rock breakers on sizes above 2 in., but they would be heavy, cumbersome and difficult to transport to the metal-mining regions, so I hold that the combination of breakers and rolls I have indicated best answers our present requirements in metal mines where the rock going to the breaker is never of unusual size—as quarry rock for example.

The idea elaborated in these paragraphs was true at the time it was written and holds good now. Perhaps the one change that may be considered justified in speaking of the matter now is that large rolls are being successfully used in many places.

In speaking of the question of rolls, it may be said that one of the principal objections to their use has been the fact that in ordinary work corrugations were almost sure to appear in the roll shells, and for this cause their crushing work was considerably reduced. To avoid excessive corrugations, it was believed necessary to have an expensive, highly skilled roll operator in charge of the work, and since individuals with this requirement were not easily to be had, it was considered an objection to the use of rolls. Improvements in the design of the machines, however, particularly the detail of successful fleeting, have brought them to the point where they can be used successfully without the peculiarly great amount of supervision that was at that time considered necessary.

Chilean Mills as Grinders

The grinding stage following rolls will depend entirely upon what is to be done with the ore. If it is to be treated by some metallurgical process that requires its passage through comparatively fine screens—say 20- to 80-mesh—the rolls may, and do in some cases, deliver direct to tube mills, while in other cases the grinding may be performed by some one of the chilean-mill type or even by finer rolls. Chilean mills are of two types—either the slow- or fast-running machines. In the first class is included mills of the older style such as were formerly used in Mexico—and of which many are still in use—in which there are usually two heavy rollers revolving slowly on a specially prepared die. The chilean mills as used at Angustias and in Pachuca have a die diameter of about 7 ft. and use rollers 7 ft. in diameter, 22 in. face, and weigh between 7 or 8 tons each. Revolutions are at the rate of 12 to 15 per minute, and capacity to 30-mesh screen is about 15 tons per day. These mills require about 15 hp. for operation. Mills of the type known as the Monadnock, the Akron, Evans-Waddell, Bryant and others, are of the high-speed type, usually having smaller die diameters (running up to 5 or 6 ft.), smaller rollers (from 3 to 4½ ft. in diameter) and operate at much higher speeds, usually in the neighborhood of 30 r.p.m. Examples of the use of such machines that are doing good work may be found at Stratton's Independence mill, near Victor, Colo., and at the Portland mill at the same place.

In referring to the use of stamp batteries, Julius I. Wile, in the *Journal* of Apr. 17, 1915, says:

> For tough ores it is probable that stamps will continue to be used on account of the high iron consumption of the ball mills on such ores, and it should be noted that on the Rand in South Africa the combination ball-and-pebble mill was tested against stamps and rejected, supposedly on account of the heavy iron consumption. The stamps generally used in America are the 5- and 10-stamp multiple batteries, the stamps being from 1,030 to 1,400 lb. falling weight. The 2,000-lb. Nissen stamp in tests on the Rand has demonstrated that it takes 25% less power and 10% less iron than the older type of the same weight, and this can be attributed to the quickness of discharge of the Nissen, due to the circular form of mortar surrounding the stamp shoe. Nissen stamps are also less costly to install when foundations and less space occupied are considered. It is well known that in the Lake Superior copper district, steam stamps have been used for years, and it would seem that here a heavy power-driven gravity stamp could be employed to advantage, as although the same power per stamp would be used for the same falling weight, it should use less fuel per horsepower than the direct steam stamp. In gold and silver milling, as cyaniding is now largely used there is no longer the objection to the use of heavy stamps on account of the slimes which would be made, and coarse screens are now used, as the finishing is done in pebble mills.

Tube mills were introduced into the metallurgical field as a direct result of the requirements of the cyanide process. When it became apparent that slimes could be treated more rapidly and with a higher extraction percentage than sands, some method of easily grinding so that

a maximum of slimes would be produced was required. The tube mill, formerly used in the cement industry—where extreme fineness is required—was adopted and almost immediately became standard practice. The overflow type of tube mill is the one most generally used, the circulation through which depends on the amount of feed and the discharge on the amount of slimes that are displaced, come to the surface of the pulp and float out at the center. The discharge of tube mills of this kind may be protected by a grid or perforated plate that will permit the exit of ground material without the loss of pebbles, or the mill may be operated without any protection at all, which is often done. In place of the grid for retaining the pebbles of the mill, a device which consists of a funnel-shaped discharge casting that is fitted to the discharge end of the tube mill was originated by Walter Neal. On the inside of this casting was placed a spiral screw-like riffle, operating in the direction opposite to the mill rotation. Any pebbles tending to escape through the discharge orifice were caught in this screw and returned to the interior of the mill. In many cases the discharge orifice was used as the point at which fresh pebbles were fed, since it was easy enough to throw them into the opening where they would be caught by the screw and delivered in the interior of the mill. In view of the fact, however, that the discharge end of the tube mill is the wrong place to use new pebbles for grinding, that practice has not been continued, and pebbles are almost universally added now at the head end of the mill through the scoop feeder.

Tube mills are of many makes and specifications, but there are only two types that have universal attention. These are exemplified by the Hardinge conical mills and the ordinary cylindrical mills. The diameter of mills that have been used heretofore has varied mostly from 4 to 5 ft., and the length from 16 to 22 ft. The tendency now, however, is toward larger diameters, running sometimes to as much as 8 ft., and much shorter lengths, a 6-ft. length being not unknown. It is believed that with large diameters and short lengths and by dividing the grinding into stages, much more economical results are obtained.

Flint and Iron Pebbles for Grinding

Flint pebbles have been used almost entirely for tube-mill grinding heretofore, the best having been obtained in the Scandinavian countries—Norway, Sweden and Denmark offering a good supply. The flint-pebble industry has grown considerably in France, however, where it is confined almost wholly to the coast line between Havre and Dieppe. A report of the United States Department of Commerce states that the pebbles collected in and near Havre are selected for their spherical shape and are used exclusively for pulverizing. Another important use of flint pebbles is in the manufacture of porcelain, but for this purpose a pebble of purer flint is used than those found at Havre. The porcelain flint is found on the French coast in the region of Fécamp and Calais. These pebbles need not be spherical, since they are utilized by being crushed into a powder, which becomes an ingredient of the paste used in the manufacture of porcelain. To some extent, however, the round pebbles found at Havre are used for pulverizing in the porcelain industry.

The flint pebbles are gathered by women and children. Prior to the war the price to pickers was 15 francs ($2.89) per ton for the best flint pebbles, and 5 francs ($0.96) for ordinary. A leading shipper reports that the quantity shipped to the United States in 1915 was about 25% less than in the preceding year. He attributes this decrease to several reasons, including the scarcity of male labor, the lack of transportation facilities and the congestion of the port of Havre, which did not permit the usual temporary storage on the quays of the bags of pebbles intended for exportation. The cost of labor has also risen steadily, as has that of transportation, and the prices of bagging used as covering has also steadily risen, thereby necessitating an increase in the prices of pebbles.

The increase of price of pebbles, together with other factors which have seemed to make it necessary, have resulted in a change of opinion toward the use of steel or iron as a substitute. Many experiments have been made on the subject, and the result is that a number of mills are making actual use of pebbles of an iron or steel composition. Those known as "manganoid" have been experimented with successfully at Porcupine and Cobalt, and in some of the mills are in regular use.

Utility of Manganese and Chrome Steel

An interesting discussion has been taking place recently relative to the comparative advantages of manganese steel and chrome steel in crushing machinery. The discussion originated in an article by Douglas Lay, describing the grinding in the Slocan district of British Columbia. This was published in the *Journal* of Mar. 11, 1916. Mr. Lay called attention to the fact that the feed-roll shells were made of manganese steel, while middling-roll shells were made of chrome steel. At the St. John del Rey mill, at Morro Velho, Brazil, manganese steel, which gave such admirable results in rock breakers and tube mills, did not compare favorably with the chilled-iron shoes and dies for the stamp mill which were made at Morro Velho. In testing two types of liners for tube mills, it was found that the one with the deep channels had a much longer life than one with shallow channels. In the discussion of chrome verses manganese steel, Frank E. Johnson, of Salt Lake City, Utah, offers some figures in the *Journal* of May 20, 1916. He found that the cost per ton milled with chrome-steel jaw plates was $0.00138, while with manganese-steel jaw plates it was $0.00054. He calls attention to the fact that in another test, run at another property during the first part of 1914, chrome-steel plates crushed 48,736 tons of ore and manganese-steel plates crushed 99,451 tons of ore. In this case both plates were made from the same pattern. As to the use of balls, Mr. Johnson observes that there are practically no manganese-steel balls used at the present time, but that he is familiar with the test in which manganese-steel balls, specially made, gave slightly better service than chrome steel. He calls attention, however, to the fact that their manufacturing cost is greater than for chrome steel, making the latter more economical.

Mr. Lay adds the further comment that in the case of feed rolls crushing material roughly 1½ in. in size, his experience is that manganese-steel shells have at least double the life of those of chrome steel. In the case of finer material the difference is not so marked, and consequently the advantage lies with the cheaper chrome-steel shell.

In the 240-stamp mill of the Alaska Treadwell Gold Mining Co., in Alaska, 1 lb. of chrome steel in shoes

crushed 2.7 tons of ore, and in the 300-stamp mill it crushed 2.44 tons. In the 240-stamp mill 1 lb. of iron in the dies crushed 5.83 tons of ore and in the 300-stamp mill, 4.09 tons. All dies used in the mills were cast at the Treadwell foundry. At the Alaska-Mexican, in Alaska, 1 lb. of chrome-steel shoes crushed 2.48 tons of ore, and 1 lb. of Treadwell dies crushed 5.34 tons of ore. At the mill of the Alaska United Gold Mining Co., 1 lb. of chrome-steel shoes crushed 2.59 tons of ore; and 1 lb. of Treadwell foundry dies crushed 6.12 tons of ore. The matter of manganese versus chrome steel for crushing machinery parts is still open, and there will undoubtedly be more discussion about it. It is apparent, also, that an effort is being made to replace flint pebbles by some metal composition, and this will probably be successful in time.

The feed to tube mills varies considerably and has usually been about 10-mesh, but the tendency at the present time seems to be toward coarser material. On regrinding work it has been found that where tube mills are fed with extremely fine material, their efficiency is considerably lessened. Attempts have been made to better this by adding a considerable proportion of coarse material along with the fine that is to be reground. For example, the Tonopah mills make a practice of adding a percentage of coarser material to their regrinding tube mills. It is claimed that a much higher duty is obtained from mills so fed. It is said that as high as ½ in. is fed to the tube mills at the Dome mill in Porcupine and a small portion of ¾-in. material is fed at the Nipissing in Cobalt. The reason is that it has been found that tube mills will handle coarser feeds, and enlarging the stamp-battery screens increases tonnage to such an extent that the per-ton costs are lowered. It is probable that this fact has been a reason for the change of crushing machines at the Dome that has already been chronicled. Here the stamps are to be replaced by ball mills, apparently the conclusion having been reached that the delivery from them is better fitted for tube milling than that from the stamps. Of course the impelling cause of any change of this sort is an ultimate saving of cost or the obtaining of better results or both. In this instance, however, it appears that the metallurgical results will be much the same, while the cost will be appreciably lowered.

It is worthy of notice that a good many of the grinding machines that were popular not so many years ago have been eliminated almost entirely from present-day metallurgical work, at least in this country. Among the machines that may be so classified are the Huntington mills, which were once standard equipment in concentrating and cyaniding plants. They have proved too expensive, however, and their maintenance cost was out of all proportion to the results obtained. The grinding pan is another machine that has dropped out of serious consideration and is now to be found very seldom in this country, although still largely used in Australia. There are one or two instances of its use lately in South America, but it has been considered here that ordinary grinding, finishing with tube mills, is preferable. Of course there always were many highly complicated machines that were designed to perform certain work, most of them peculiar in appearance and operation, but it is hardly worth while to go into details of machines of this class. One of them that did good work for a time and then was superseded by more efficient machinery, was known as the Kincaid mill. It is very seldom used at the present time. A common fault of the Huntington mill, which has just be mentioned, was the uneven wearing of the roller rings. Instead of wearing evenly to successively smaller concentric circles, they frequently assumed polygonal shapes and then pounded around the inside of the die ring instead of rolling in continuous contact with it. When this fault becomes aggravated the grinding falls rapidly.

The Marathon Mill

A new mill that is being tried for finishing grinding is known as the Marathon mill. It consists of a drum or tube, similar to the ordinary tube or ball mill in which pebbles or balls used for crushing are replaced by cylindrical steel rods, or shafting. The mill contains a charge of these rods sufficient to do grinding work, and the tube is revolved at a speed comparable with that of the tube mill. Grinding is performed by the falling of the pieces of cylindrical steel rods one upon the other, or by their attrition against each other. It is claimed that by the use of rods instead of pebbles or balls, the pulp is subjected to more grinding action, as in contradistinction to the mill charged with pebbles, the contact is over a long line instead of being limited to a point. A test of the Marathon mill has been carried out at the concentrator of the Detroit Copper Mining Co., of Arizona, at Morenci, in which the advantages of the mill have been pointed out. The diameter of the rods used varies from 2 in. to ⅜ in., these various diameters causing them to fit compactly and thus requiring a minimum falling distance to deliver a crushing blow. The center of gravity of the charge of rods is nearer the axis of the mill than in a mill of greater diameter whose crushing charge consists of steel balls or pebbles.

A characteristic of the Marathon mill that has been developed at the Detroit concentrator is that the discharge of the mill is uniform whatever the feed, or, in other words, if the feed to the mill is increased, the product is uniformly coarser, and if the feed is diminished, the product is uniformly finer. The result, according to this, indicates that the discharge from the Marathon mill is uniform, and does not consist of great differences of oversize and undersize, as is the case with most grinding machines of the type.

Two tests were made of the Marathon mill, and in the first test the most favorable results were obtained with a pulp which contained 36.7% solids. In test No. 2 the amount of water and slime in the feed was reduced to a minimum by shovel-wheels to secure a less volume of pulp and a consequent slower velocity of material through the mill. The tonnage in test No. 2 was greatly increased over that in test No. 1. The feed contained an average of 63.5% solid and only 2.92% minus 200-mesh slime. The speed in all of the tests of the Marathon mill was 30 r.p.m. In a diameter of 3 ft. at 30 r.p.m., there is no dead zone in the periphery of the mill, while excessive slipping of rods is prevented by having the liner plates thicker at each edge than in the middle. This results in a corrugated interior surface, and the lining is said to retain these corrugations until it is worn out. The rods are said to wear evenly from end to end, do not get crosswise in the mill, and are reduced to a diameter of ⅜ in. before they begin to crush, flatten out or break into pieces. When worn to this thinness, some rods roll up and are discharged; the short-length pieces retain their positions in the charge of rods without any serious result,

but may reduce crushing efficiency to some extent. It is said to be good practice to take out the entire charge of rods every ten days, take out the small and disabled rods, and replace the loss in weight with 1¼-in. rods. As soon as the weight of rods consumed per day was determined, their loss in weight was replaced daily with fresh rods. The mill must be closed down to add the daily charge of rod. During the test the Marathon mill was tilted ¼ in. per ft., but later tests showed that it would produce equally as good results when run horizontally.

In No. 1 test the Marathon mill crushed 236.5 tons of dry feed in 24 hr., and in test No. 2 the mill crushed 440 tons of dry feed per 24 hr. The horsepower consumed per hour in test No. 1 was 18.6 and in test No. 2, 22.5. This makes 0.5316 tons of dry feed per horsepower-hour in test No. 1 and 0.8148 tons of dry feed per horsepower-hour in test No. 2.

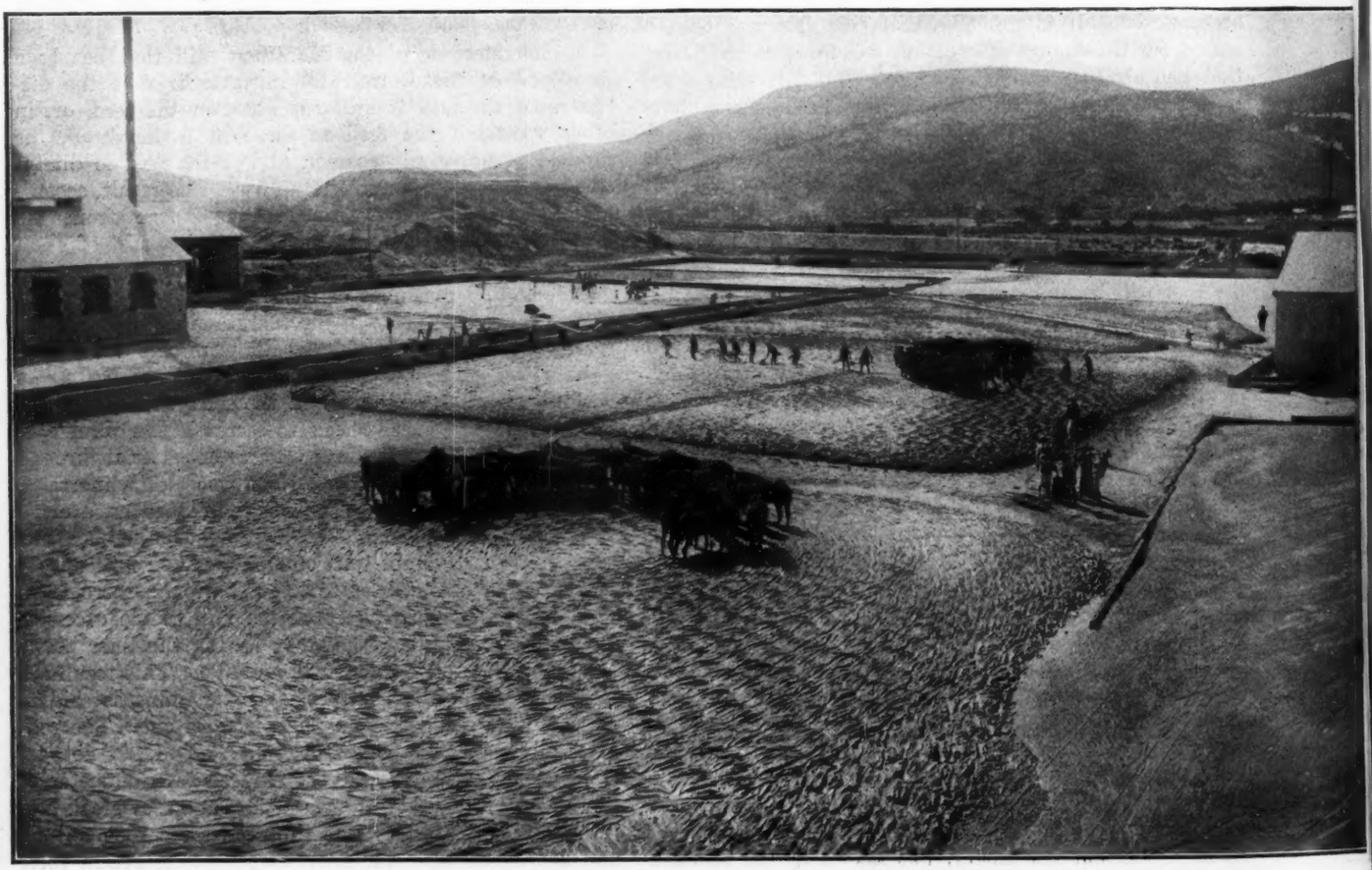
Miami's New Power Plant

Perhaps the most important improvement that the Miami Copper Co. has in hand is the new Diesel power plant. This new addition embodies some interesting equipment and an important saving in operating cost over the present unit. The equipment includes three Nordberg-Carels Freres Diesel engines of 1,250 hp. each, sea-level rating, direct-connected to General Electric 6,600-volt alternating-current generators. Allowing for altitude, the output of each generator is expected to be at least 720 kw. The new power installation, including buildings, will cost not far from $300,000, but there will be a saving of about $75,000 per year in operating cost over the present steam plant, which is today perhaps the most efficient in the Southwest, having an over-all thermal efficiency of 12.75%. The oil consumption of the Diesel plant is expected to be about one-half that of the present steam plant, which burns oil under the boilers. A thermal efficiency of approximately 30% is expected from the new Diesel plant.

The Patio Process

The patio process is the great classic of silver metallurgy. Previous to its invention the recovery of silver was by slow, expensive and laborious methods that produced only small quantities at a time. The advent of the patio process marked the beginning of the enormous production of silver that came from the Spanish-American countries, a production that has grown gradually and continually up to the present time.

The patio process was invented by Bartolomé de Medina, at Pachuca, Mexico, in 1557. While it is still in use in a few isolated localities in Mexico and other Latin-American countries, it has practically disappeared from serious metallurgy and is only used as an alternative in highly specialized cases where a small amount of ore of a particular class is to be treated. The use of the system began to decline about the time of the invention of the Washoe process, which was applied to the silver ores of the Comstock lode in Nevada. It was still largely in use up to about 1900, but not far from that time the production of the pan process and the



THE OLD PATIO IN OPERATION AT HACIENDA GUADALUPE OF THE SANTA GERTRUDIS

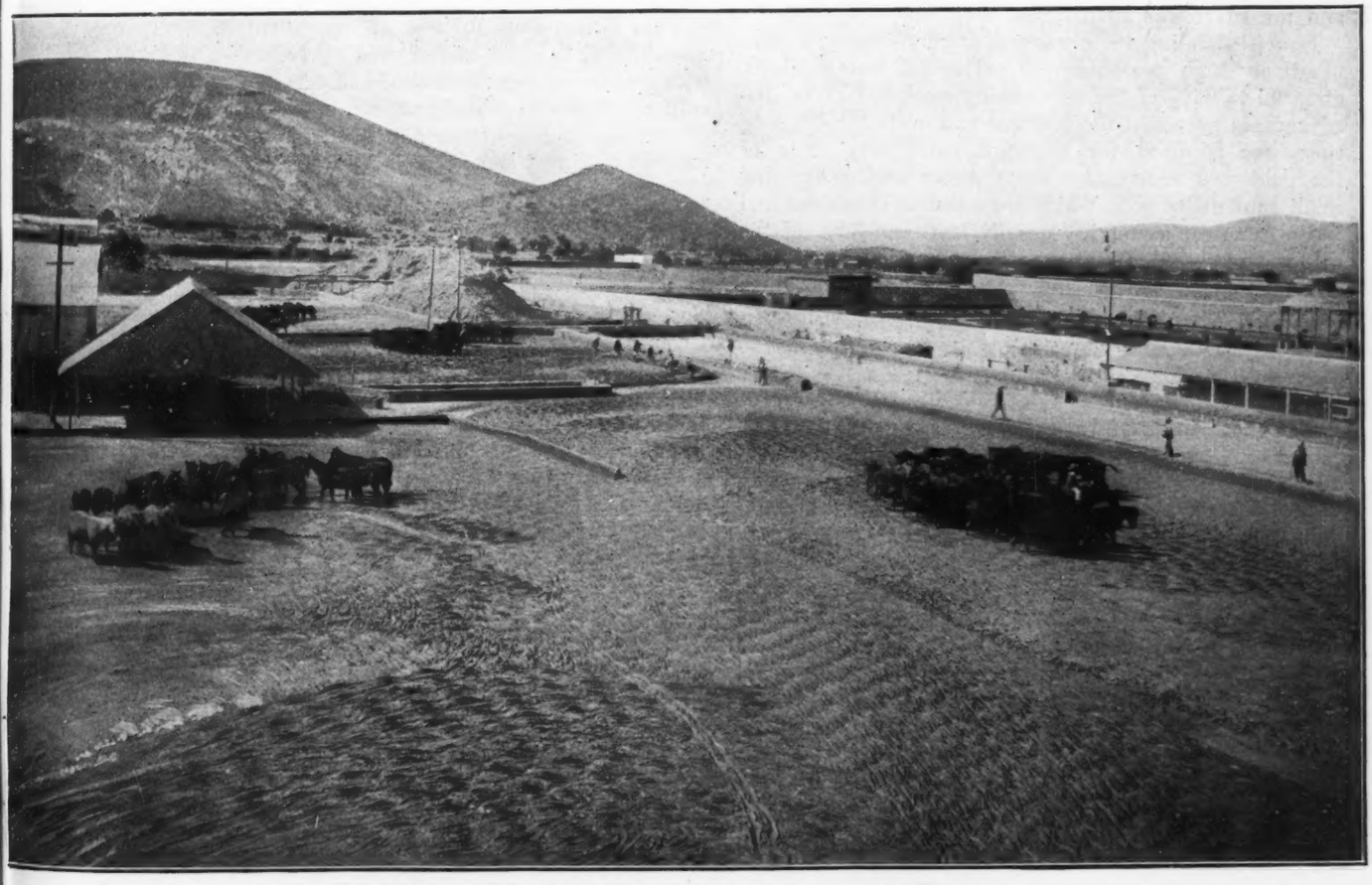
advent of cyanide retired it rapidly into the class of those processes that have been famous but exist no more.

The institution of the process at Pachuca brought into production the famous mines of that camp, which continued to be worked profitably by the same process until about 1905 or 1906, although more modern processes had been instituted before that time. The patio process has also accounted for much of the immense volume of silver that was produced from the famous Mexican camps of Taxco, Guanajuato, Zacatecas, Chihuahua and all those other famous mining camps that gave Mexico its reputation as a silver producer and added immense wealth to the Spanish throne. It likewise accounted for immense productions of silver from the other Latin-American countries.

The patio process is adapted to treating ores in which silver occurs as a simple sulphide—argentite—or the complex antimonial and arsenical combinations that occur so often in the large North and South American silver deposits. In carrying out the process, the ore is first broken down by some means to a size such that it can be handled in the chilean mill, another invention of Latin-America for the metallurgy of precious-metal ores. The chilean mill, as everyone knows, consists of a heavy roller crushing ore on a die, which is a circular track in the ground. The original chilean-mill roller was cut from stone, and the size of the wheels varied from 5 to 8 or 10 ft. in diameter, the face running up to 20 or 25 in. in width. The die upon which this wheel rolled was also built of hard stone, the diameter of the track varying considerably in different instances and sometimes reaching as much as 15 ft. or more. A shaft was passed through the center of the roller, one shaft end being made fast to a vertical stake in the center of the mill, the other extending out beyond the track and being moved by mules or horses hitched to it.

In the chilean mill the ore was broken down to a size varying from very fine material up to pieces ¼ in. or ½ in. in diameter. This material was then taken to another grinding machine known as the arrastre. As was the case with the chilean mill, this machine was built in the ground and consisted of a stone-paved track of circular shape, having a central vertical stake and an arm reaching from that stake out across the track and being moved by mules or horses, just as the chilean mill was actuated. The grinding, however, was done by large, heavy, flat stones, as hard as could be secured, one end of which was attached by rawhide thongs or chains to the horizontal arm of the machine. The length of the connecting chains was made so that the front end of the flat stone was slightly lifted from the bed of the arrastre, the rear end dragging on it. With this machine water was added to the ore or not, as the case seemed to require, and the flat stones were dragged around, grinding the ore to a fine powder or paste between the heavy drag stones and the paved floor of the machine.

Having ground the ore to the required fineness, which was just as fine as could be secured and usually consisted of a pulp containing a large proportion of minus 200-mesh material and varying portions of granular material averaging perhaps about 40-mesh grade, it was then drawn from the arrastre and taken to the patio.



COMPANY AT PACHUCA, MEXICO, A TYPE OF ANCIENT SILVER-RECOVERING PROCESS

This was simply a large floor or yard paved with flagstones or some other smooth material. It was not covered, since the air and sun were required for the carrying out of the chemical part of the process. These patios often reached several acres in extent. The pulp on the patio contained enough water to make a pasty mass of it, but not enough to allow it to run.

The actual metallurgical process commenced by the addition of salt and copper sulphate to the mass, which was then thoroughly mixed by men with shovels, aided by a troop of mules or horses that were driven around in the mass. After the salt and copper sulphate had completed the chemical work required, quicksilver was added to the mass, or *torta,* as it was called, and the mixing and treading process began again. This was continued until thorough amalgamation of a great portion of the silver was secured.

In many cases common salt derived from evaporation of salt-lake waters or mined from rocks was used, and the copper sulphate employed in the early days was the *magistral,* or crude copper sulphate coming from the mines. The amalgamation of silver in the patio process was assisted by action of the air and sun, and frequently took thirty or more days to accomplish extraction of the maximum amount of silver from a single *torta.* Having reached the highest possible extraction, the *torta* was taken into large settling tanks, much like the mechanical cyanide agitator, in which the pulp was diluted with a large quantity of water, kept in slow motion and the quicksilver allowed to settle to the bottom, while the pulp containing the ground ore was allowed to float away. The quicksilver and amalgam recovered was retorted, and the silver was melted into bars.

Notwithstanding the crudeness of this process, a comparatively high percentage of extraction was obtained, often 90 to 93% of the silver being recovered. The disadvantages were that the cost was extremely high, a long time was required for operation, and very little of the gold was recovered. From silver ores containing small amounts of gold, which are common in Mexico and Latin-American countries, usually less than 30% of the gold was recovered. Great quantities of patio tailings have accumulated in Pachuca and Guanajuato, some of which is being worked over again.

Aluminum Industry

E. Collett, in *Polyteknisk Forenings,* Christiania, Dec. 16, 1915 (through *Journ. Soc. Chem. Ind.,* Mar. 31, 1916) says that the world's production of aluminum in 1912 was 60,000 metric tons; for 1915 an output of 100,000 tons was anticipated, but owing to the war barely 80,000 tons was made. The present price of aluminum in Norway is 3 to 4 kr. per kg. (1s. 6d. to 2 s. per lb.). Crude bauxite is now freed from silicates and impurities for the European aluminum industry in the south of France. The conditions for the production of the metal by thermo-electrolysis are particularly favorable in Norway. For the production of 1 ton of aluminum 5 hp.-yr. is required. Outside Norway the cost of 1 hp.-yr. is estimated at about 50 kr. (£2 15s.), or 250 kr. (£13 15s.) for 1 ton of the metal (25% of the total cost). In Norway the horsepower-year costs only 20 kr. (£1 2s.), or 10% of the total cost of production, owing to the cheapness of water power.

Mercury from Zinc Blende

F. Juretzka, in *Metall u. Erz,* 1915, XII, 307, *Chem.-Zeit.,* 1915, XXXIX, Rep., 443, and *Journ. Soc. Chem. Ind.,* March 31, 1916, says that zinc blende from the Rhine district contains at times 0.005 to 0.01% of mercury, probably due to an admixture of fahl ore. When the blende is roasted the mercury vapor escapes with the gases, and when these are utilized for the manufacture of sulphuric acid, the mercury is deposited partly before reaching the Glover tower and partly in the Glover tower and in the lead chambers. Sludge from the Glover tower contains 5 to 8% and that from the chambers 3 to 5% Hg. The sludge is drained, mixed to a stiff paste with "lime-sand" (waste from lime burning) and then with just sufficient lime to neutralize the acid, and the mercury recovered by distillation at a dull-red heat.

Reduction of Roasted Zinc Blende

V. Lindt, in *Metall u. Erz,* 1915, XII, 335 (through *Journ. Soc. Chem. Ind.,* Mar. 31, 1916), reports that in the reduction of roasted zinc blende of low sulphur content (2 to 3%) sulphide-sulphur acts injuriously when the ratio of zinc to sulphide-sulphur is less than 10 : 1 and favorably if this ratio is 18 : 1. Sulphate-sulphur is detrimental to the reduction of roasted blende containing 1 to 2% of sulphide-sulphur when the ratio of zinc to sulphate-sulphur is 4 : 1 and favorable when the ratio is 5 : 1. In the case of products with a relatively high content of sulphide- and sulphate-sulphur, the sulphur acts injuriously on the reduction if the ratio of zinc to sulphide-sulphur is less than 20 : 1 or of zinc to sulphate-sulphur less than 6 : 1. The loss of zinc on reduction is higher with products, free from lead, in which the sulphide-sulphur is present entirely as iron sulphide, and in those of very low iron content or in which the iron is present entirely as zinc ferrite, than in other cases.

Lime-Iron Singulosilicates

The properties of the system $2FeO.SiO_2 + 2CaO.SiO_2$ have been recently examined by B. Selivanoff (*Rev. Soc. Russe Metall.,* November, 1915; abstr. *Journ,* Soc. Chem. Ind., Mar. 15, 1916), who melted silica, lime and iron peroxide in an iron crucible in an electric resistance furnace. Fe_2SiO_4 melts at about 1,260° C.; there is a maximum at about 1,260° C. corresponding to $2Fe_2SiO_4.4Ca_2SiO_2$, and between these two points is a eutectic at about 33% (molecular) Ca_2SiO_4 and about 1,160° C. Heated in a current of hydrogen, reduction begins at about the following temperatures:

Fe_2SiO_4	100%	85%	65%	50%	40%	30%
Temperature, deg. C.	225	210	205-210	170	180	250

Improvements at Miami Mill

The May output of the Miami Copper Co. of 4,600,000 lb. of copper established a new high record for that company. The capacity of the mill at Miami, Ariz., will be gradually increased to permit a monthly production of 5,000,000 lb. of copper. The 100-ton experimental mill for the treatment of the low-grade ore has shown an extraction of over 80%. Among other improvements an Miami is the proposed $75,000 Y. M. C. A. building, plans for which have just been approved.

Editorials

The Ore-Milling Industry

This issue of the *Journal* is devoted especially to matters relating to the milling of ores, by which is understood chiefly the methods of mechanical concentration. Other branches of milling are cyanide lixiviation—with which mechanical concentration is frequently combined, copper lixiviation and zinc lixiviation. These processes merge into the metallurgical as distinct from the simply mechanical processes of separating valuable minerals from worthless gangue, which constitute the bulk of our milling.

The importance of the art of milling is nowadays but slightly subordinate to the art of mining, for except in the case of iron ore nearly all the ore that is mined has to be milled for the purpose of concentration. At the present time the United States is mining copper, lead, zinc, gold, silver and miscellaneous ores, exclusive of iron ores, at the rate of about 76,000,000 tons per annum and is milling about 70,000,000 tons thereof. The great bulk of this immense quantity is milled by purely mechanical methods—jigging and tabling in the most cases, jigging and tabling combined with flotation in many cases, and flotation alone in a few cases. The other mechanical processes—magnetic and electrostatic separation—are of subordinate importance, but in a few instances, as in the magnetic treatment of the mixed zinc ores of Franklin, N. J., are of the first order in consideration.

The great thing in milling in recent years has been the development of the flotation process, which has enabled a greatly increased extraction of mineral to be made at but slight, if any, increase in cost—either in plant or in operation—over the old-fashioned jig and table mills. In view of the supreme importance of the flotation process, a large part of this number of the *Journal* is devoted to it.

This issue is a special number for millmen, and its space is given almost entirely to their subject. It is not designated to be a compendium on the art of milling, but simply a collection of useful memoirs, articles and notes on matters of current interest. The large amount of space given to the flotation process is in line with the general interest in that process.

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Two Notable Mining Reports

As a general thing annual reports of foreign mining companies do not impress us at all favorably when compared to the classics put out by our own large companies, but two foreign reports are in hand that challenge our interest and respect.

The Tharsis Sulphur and Copper Co., operating pyrite mines in Spain, has completed the 50th year of its existence, which it announces very unostentatiously as it does also that during this period a dividend has been paid each year, amounting to a grand total of over £10,250,000. The mines were actively worked by the Romans, but according to the chairman's statement at the annual meeting, it is doubtful if they have yet reached middle age. A dividend of 10% was paid for 1915, despite a considerable sum carried to surplus and despite increase of more than half a million dollars in freight rates and income tax.

The report of the British South Africa Co., controlling North and South Rhodesia, for the year ended Mar. 31, 1915, shows total assets of £16,744,773. There are many mining companies showing greater resources than this, but this report does not impress us as a company report; it is really the "gray book" of an empire. War, customs levies, ranches and crops, agricultural experiment stations, mining, railways, immigration and national health are some of the few problems of its directors that are unassumingly set forth.

Under mining a figure of general interest is the increase in the mineral production of Southern Rhodesia from £3,883,001 in 1914 to £4,399,070 in 1915. This includes £3,823,167 in gold, 185,233 oz. of silver, 409,763 tons of coal, and 60,581 tons of chrome-iron ore. The coal output was all by the Wanki colliery, the chrome output by the Rhodesia Chrome Mines, Ltd. In Northern Rhodesia, the gold output was £3,953; silver, 4,066 oz.; copper, 813 tons; and 5,740 tons of 60 to 70% bismuth ore. Claims have been registered for gold, silver, iron, lead, zinc, bismuth, graphite, mica, molybdenum, platinum, tin, coal, nitrate and lime.

It is to be imagined that the shareholder who receives this report must read it with the feeling that, however far off monetary dividends are, there is a certain return on this investment that no other company will ever give.

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Gold and Silver Production in 1915

The revised and corrected statement of gold and silver production in the United States in 1915, prepared jointly by the Bureau of the Mint and the Geological Survey, has been issued, and shows that the preliminary statement made last January was conservative in its estimates. The revised figures give the total production of gold in 1915 at 4,887,604 ounces, fine, or $101,035,700, and the total silver was 74,961,075 ounces, fine. At the average price in New York, the commercial value of the silver was $37,397,300, making the total value of the precious metals last year $138,433,000. These figures are an increase over the preliminary estimate of $2,144,600 in gold and 7,475,475 oz. silver. The larger difference in silver was probably due to an underestimate of the quantity contained in copper bullion.

As compared with the report for 1914, the total gold production of 1915 showed an increase of $6,503,900, or 6.9%, while there was an increase in silver of 2,505,975 oz., or 3.9%, instead of the decrease indicated by the preliminary statement. The figures for both years, 1914 and 1915, are given in the accompanying table, gold in value and silver in fine ounces.

In gold production California came first in 1915, with an increase of $1,296,000. Colorado, with a much larger

gain, took the second place, being only $16,600 behind California. Alaska was third, Nevada fourth and South Dakota fifth, all three with only small gains. Ten states produced over a million each, while the Philippine Islands reported a gain of 22%, to a total of $1,320,900, a considerable share coming from dredging operations largely financed from Australia and New Zealand.

In silver production Nevada was first and Montana second with a difference of less than 30,000 oz. Utah held

GOLD AND SILVER PRODUCTION OF THE UNITED STATES

(Gold, Value; Silver, Fine Ounces)

	Gold		Silver	
	1914	1915	1914	1915
Alabama	$12,300	$5,100	300	.....
Alaska	16,547,200	16,710,000	865,900	1,054,634
Arizona	4,568,900	4,555,900	4,439,500	5,665,672
California	21,251,900	22,547,400	2,020,800	1,689,924
Colorado	19,902,400	22,530,800	8,804,400	7,199,745
Georgia	16,800	34,800	100	141
Idaho	1,187,200	1,170,600	12,573,800	13,042,466
Illinois	.....	.....	1,900	3,892
Maryland	200	.....	100	.....
Michigan	.....	.....	415,500	581,874
Missouri	.....	.....	60,000	55,534
Montana	4,143,600	4,978,300	12,536,700	14,423,173
Nevada	11,536,200	11,883,700	15,877,200	14,453,085
New Mexico	1,219,100	1,460,100	1,771,300	2,337,064
North Carolina	130,300	170,700	1,500	1,496
Oklahoma	.....	.....	6,200	.....
Oregon	1,589,400	1,867,100	147,400	125,499
South Carolina	3,200	3,600	.....	.....
South Dakota	7,334,000	7,403,500	179,800	197,569
Tennessee	6,400	6,800	102,800	99,171
Texas	8,800	1,800	574,700	724,580
Utah	3,377,000	3,907,900	11,722,000	13,073,471
Vermont	.....	.....	.....	150
Virginia	300	500	1,500	.....
Washington	587,800	461,600	341,300	213,877
Wyoming	6,700	13,900	100	2,910
Continental U. S.	$93,429,700	$99,714,100	72,444,800	74,945,927
Philippines	1,099,300	1,320,900	10,300	15,148
Porto Rico	2,800	700	.....	.....
Total	$94,531,800	$101,035,700	72,455,100	74,961,075

the third place and Idaho fourth. Colorado and Arizona were next in order, the former showing a considerable loss from the previous year, while Arizona made a gain.

Silver and Flotation

Silver producers have good reason for watching with extreme interest the development of the flotation process. Any metallurgical development that will enable silver ores of lower grade to be worked, or that will permit other ores carrying small percentages of silver to be beneficiated at a profit, will have an influence upon the total silver production. Since a large portion of the world's silver is produced in the United States and Mexico, the silver-producing mines of the latter unhappy country being largely under American direction, improvements in the metallurgy of that metal are particularly interesting to operators here. As flotation may allow the working of zinc and lead ores containing small quantities of silver such as were not economically profitable under previous conditions, the wide application of flotation is likely to bring an additional amount of silver into the market. It has already had that effect in some portions of the United States, and when Mexico reaches a condition such that her mines may be operated, a further amount will be produced. In addition to the silver that will be recovered from base-metal ores that carry silver incidentally, it may reasonably be expected that further quantities will be produced from low-grade ores carrying silver, together with possibly some gold, as the metal of principal importance. There has been some difference of opinion as to the extent to which flotation will be applicable to silver ores, but it may be expected that low-grade slimes containing silver in connection with iron sulphides will be brought within the range of flotation and that an additional amount of silver may be brought into production from that source. The Mexican silver ores consist largely of argentite that occurs with iron sulphide, and the bulk of the tailings losses in silver-treating mills may be reasonably said to consist of finely divided material of this kind that goes to waste with slimes. Some of it cannot be recovered economically on concentrating tables, and it is reasonable to believe that much of it may eventually be saved by flotation methods. In fact, it is not without the bounds of reason to say that the slimes from ores of this class may be treated more cheaply and with a higher percentage of recovery than by the cyanide process, and it is not impossible that flotation will be largely applied to that work. Just as the cyanide process brought within the range of economical beneficiation ores that formerly could not be handled at a profit, so flotation may be expected to lower still more the tailings, decrease treatment costs and so account for the production of a considerable quantity of silver that has heretofore not been available.

The Metal Markets

The metal markets have been dull and reactionary for about two months. Last week speculators in stocks awoke to this and the metal shares were hammered down severely. The Wall Street organs took up the talk that had already been rife in some producing districts and expressed opinions as if calamity had overtaken the metal industries. Now, in fact, copper at 26c., lead at 7c., spelter at 10c., antimony at 19c., quicksilver at $75 and tungsten ore at $30 are not low prices. With respect to most of them they are prices that are from 1½ to 2 times above the normal. They are low as compared with what they were when they were about five times above normal as they were in all cases except copper and lead. But what can people expect? Apparently having been given an unexepected treasure like Aladdin's, nothing would suit them but even bigger things. When the end was reached, there was a reaction in sentiment. This is one of the penalties of extravagance.

The consumption of metals is still continuing on an unprecedented scale and bids fair to keep on doing so. The trouble with prices is that too many people wanted naturally to share in the great profits that were being made and therefore increased the production. Conditions will be healthier in all ways if prices recede to lower but still profitable levels.

Attention is to be called to the four pages of drawings of useful kinks for the mill and for the engine room that appear in this issue. These drawings are made by a new and ingenious method invented by Arthur Ormay, chief draftsman of the Hill Publishing Co., and show the introduction of a truly artistic spirit into the art of mechanical drawing. The plates that we reproduce appeared originally in our sister publication, *Power,* to which we are indebted for them, as we also are for the two instructive plates showing the thermal balance of the steam-power plant.

The index for Vol. 101 of the *Engineering and Mining Journal* will be mailed with this issue. Any subscriber not receiving a copy of same should notify the subscription department at once.

PERSONALS

W. S. Grether, lately at Salmo, B. C., is now at Butte.

Karl F. Klein has gone from New York to Morococha, Peru.

James J. Dowd, lately at Rolla, Mo., is now at Houghton, Mich.

E. E. Reyer has gone from El Paso, Tex., to Colorado Springs.

D. W. Minier, lately at Goodsprings, Nev., is now at Los Angeles.

Dr. A. T. Roos, of Deadwood, S. D., is in New York for a short visit.

Fred G. Beckner, late at Nevada City, Calif., is now at Osceola, Nev.

Rolla E. Clapp, recently at Salt Lake City, Utah, is now at Los Angeles.

J. E. Barcus, recently at Albany, N. Y., is now at Guane, Pinar del Rio, Cuba.

R. H. McHardy has gone from Minneapolis, Minn., to Cananea, Sonora, Mexico.

A. F. Duggleby, recently at Butte, Mont., is now with the Juragua Iron Co., at Santiago de Cuba.

Louis S. Cates, general manager of the Ray Consolidated, was a recent visitor in New York and Boston.

R. L. Lee has been appointed superintendent of the smelting plant of the Central Chili Copper Co. at Panulcillo, Chile.

W. E. Thorne has entered into a new contract for two years more with the Lenskoie Co., of Siberia, for selecting dredging and hydraulic ground and sampling same.

Prof. William Nicol, of Queens University, Kingston, Ont., has resigned as professor of mineralogy, a position which he has held since the School of Mining was founded, in 1893.

Fernando Cardenas and **Miguel M. Gomez,** of Havana, have been in New York recently in connection with the shipment of a cargo of ore from the Candida, a new copper mine in western Cuba.

M. A. Rowan, who has been engaged on valuation work for the People's Gas Light and Coke Co., of Chicago, has resigned to take charge of the mining-engineering department of the Chicago & Eastern Illinois R.R., with headquarters at Nokomis, Ill.

William H. Warren has been appointed general manager of works of the Brier Hill Steel Co. at Youngstown, Ohio, and George F. Alderdice has been made vice-president of the same company, succeeding Rollin C. Steese, who formerly held both positions.

W. C. Bulmer has been appointed to succeed L. M. McDonald as superintendent of the openhearth and bessemer departments of the Ohio works of the Carnegie Steel Co. at Youngstown, Ohio. **Jacob A. Reisinger** has been appointed assistant to Mr. Bulmer.

George A. Guess, professor of metallurgy at the University of Toronto, has been engaged by the Vermont Copper Co. to start up the copper smeltery at South Strafford, Orange County, Vt. The furnace has not been operated successfully and has been idle for several years.

Percy E. Barbour, mining engineer and managing editor of the "Engineering and Mining Journal" resigned his commission as 2nd Lieutenant in the Maine Coast Artillery in order to accept a commission as 1st Lieutenant in the 22nd Corps of Engineers, N. G. N. Y., and is now at Camp Whitman preparatory to going to the border with his battalion.

H. Kenyon Burch, chief engineer of the Inspiration Consolidated Copper Company, has completed his work pertaining to the design and construction of the plant, and will leave on July first for an extended vacation trip throughout the East. His forwarding address for the next few months will be, care of The Sierra Madre Club, L. A. Investment Bldg., Los Angeles, Calif.

OBITUARY

Lieut. Carleton C. Green, well known throughout northern Ontario as a mining journalist and formerly connected with the Cobalt "Nugget," has been killed in a recent engagement. His home was at Haileybury, Ont., and he leaves a widow and two children.

SOCIETIES

American Electrochemical Society—Second National Exposition of Chemical Industries will be held in New York all through the week of Sept. 25-Oct. 1. The American Electrochemical Society will be one of the important national societies which will meet in New York during the same week. Its meetings will be held on Sept. 28, 29 and 30, and the outline of the program has just been announced, showing a varied series of papers and discussion, besides visits to the Exposition, receptions, etc.

American Society for Testing Materials—The nineteenth annual meeting was held at the Hotel Traymore, Atlantic City, June 27 to 30. As usual, the program was unusually complete and this year contained a total of 53 topics. Nine sessions were held, the fourth on Wednesday morning, June 28, devoted to the discussion of steel and iron. The following committee reports were presented: On steel, by C. D. Young, chairman; on heat treatment of iron and steel, by Albert Sauveur, chairman; on corrosion of iron and steel, by S. S. Voorhees, chairman; on magnetic properties of iron and steel, by C. W. Burrows, chairman. Nonferrous metals were discussed at the eighth session on Friday morning.

American Society of Mechanical Engineers—Ira N. Hollis, president Worcester Polytechnic Institute, Worcester, Mass. has been nominated for president for the year beginning with the annual meeting in December. The nominations for the three vice-presidents, who serve for two years, are: Prof. Charles H. Benjamin, Purdue University, Lafayette, Ind.; Prof. Arthur M. Greene, Jr., Rensselaer Polytechnic Institute, Troy, N. Y., and Charles T. Plunkett, president Berkshire Cotton Manufacturing Co., Adams, Mass. The three nominations for managers are: Prof. Robert H. Fernald, University of Pennsylvania; Prof. William B. Gregory, Tulane University, New Orleans, and C. R. Weymouth, San Francisco. Major William H. Wiley, who has been treasurer since 1884, has been renominated.

INDUSTRIAL NEWS

Chalmers & Williams, of Chicago, have recently shipped four 48-in. Symons fine-reduction disk crushers for the mill of the Federal Lead Co., at Flat River, Mo.

Murex Co., Ltd., has moved its office and laboratory from San Francisco to Darwin, Inyo County, Calif., where a mill is being built to treat the lead-carbonate ores of the Darwin Development Co. by the Murex process.

The Marks Pulverizing, Mining and Milling Machinery Co., of Los Angeles, has moved into its new quarters at 712 North Main St., Los Angeles. A test mill is being operated at this address to demonstrate the Marks centrifugal impact pulverizer.

The General Naval Stores Co., of New York announce that it will hereafter carry stocks of G. N. S. flotation oils in Denver and will be in a position to fill orders from that point within the next 30 days. John D. Davis, with office at 1550 Glenarm St., Denver, is the Colorado representative.

Weston B. Lazear has recently assumed charge of the New York office, and adjacent territory for the Stephens-Adamson Manufacturing Co., Aurora, Ill. Mr. Lazear is already acquainted in this territory and has devoted the past seven years to the design of "S-A" conveying, elevating, screening and transmission machinery.

The Executive Departments of the Western Electric Co., Inc., at New York moved on June 5 from 463 West St. to new offices in the Telephone and Telegraph Building at 195 Broadway. The move was made necessary by the steady growth of the company's engineering departments which will occupy the space that has been vacated. The local New York distributing department and the engineering and patent departments remain at 463 West St.

The A. M. Byers Co., Inc., Pittsburgh, maker of wrought-iron pipe, which also owns and operates Mattie furnace at Girard, Ohio, has leased for three years the plant of the Susquehanna Iron Co. at Columbia, Penn. The plant consists of the Columbia works and the Susquehanna works, the two being a quarter of a mile apart. The lease was made from W. W. Griest and associates, who have controlled the mills for some years. D. F. Manice, now in the Pittsburgh mills, has been appointed manager of the Columbia works, L. M. Johnston being general manager.

Editorial Correspondence

SAN FRANCISCO—June 22

Three Large Oil Tankers, costing a total of approximately $4,000,000, are under contract for construction at the Union Iron Works Co. shipyards in San Francisco. The new tankers are for the Pan-American Petroleum Transport Co. They are similar in design to those constructed for the Standard Oil Co. and are to be 435 ft. long, 56 ft. wide, with a capacity of 70,000 bbl. of oil each. The Standard Oil Co. is also having 7 more new tankers built for delivery within 18 months.

Decision in the Smelter-Fume Suits against the Penn Mining Co. in the U. S. District Court at San Francisco was announced in the "Journal" of June 17 to be in favor of the defendant in the first six cases. Eleven more of these cases are set for trial on Sept. 5. The jury required but one-half hour on June 9 to bring in the verdict. In the first six cases, the farmers claimed that the fumes from the Campo Seco smeltery reduced the amount of crops and worked a permanent injury to the soil; also that some of the stock, cattle and hogs had died from arsenic poisoning; and that wire fences were rapidly destroyed, the life of the wire being reduced from 15 or 20 years to 3 or 4 years. The farms represented in the six cases are situated at from 5½ to 7½ mi. from the smeltery. The plaintiffs rested their case on the testimony of the owners of the land interested in these suits, without calling as witnesses the veterinary surgeons, Dr. Fox, Dr. Kreely and others as expert witnesses, as was expected would be done. The defendant presented evidence of Charles Bartels, chemical engineer, who was one of the experts of the Selby commission and C. E. Bigler, agricultural chemist of the West Scramento Co., and the Natomas Co. Evidence was adduced showing that careful examinations had been made of the vegetation and soil and determinations of the amount of sulphur dioxide by approved chemical processes, showing that the amount of sulphur trioxide was in every case less than 1 part per million. In a large number of experiments in which growing plants were submitted to sulphur dioxide and sulphuric acid in moving air, there was no injury whatsoever where the concentration was less than 8.1 parts per million. Other experiments and tests were made embracing the entire growing period and it was found that where concentration was less than 5 parts per million, there was no effect upon the growth of vegetation or upon the amount of the crop. The shallowness of the soil and the rotation of crops was alleged by the defendants to be the actual cause of the decrease in the amount of crops on these farms since 1910. These farmers do not plow deeply, which is so essential to the growing of good crops in the foothill farming regions of California. The attorneys for defendant contended that damage done to wire fences was due to electrolysis.

BUTTE—June 22

The Accident Record for April in Butte was one of the best in the history of the mines. The total number of accidents in the 27 mines of the Anaconda company in the 30 days was only 35, or an average of 1.15 to the 10,000 shifts. In 13 of the mines there was not a single accident.

North Butte Stockholders here have suspected a persistent effort on the part of interests with influence to make a special bear target of that stock. North Butte was for years a discredited mine because it was at that time managed with an eye to the stock market, rather than developing the property in the interest of the stockholders. The present management is making a sincere effort to rehabilitate the property. If reports from the mines can be believed there is a decided improvement in the property, much new ore having been disclosed by the recent development.

A First-Aid Contest has been carried on for many weeks between 12 teams, representing the mines of the Anaconda Copper Mining Co. in Butte. An increase in the amount of the prizes has just been announced. The first prize instead of being $150 in cash will be $200. Instead of only three cash prizes of $150, $100 and $50, there will be prizes for seven out of the 12 teams and keen interest is being taken in the final battle for positions. The cash-prize awards will be as follows: First team, $200; second, $150; third, $125; fourth, $100; fifth, $75; sixth, $50; seventh, $25. This makes a total cash distribution of prizes by the Anaconda company of $725 instead of $300 as at first planned. It had been expected to give silver medals also to the winners and bronze medals to the members of the second team. These medals were to be supplied by the National Safety Council with which the American Mine Safety has been merged. It now develops that its medals cannot be awarded for contests in which competition is limited to teams representing only one company. This was the reason for increasing the cash prizes. Apparently the Moonlight Mine team will win the $200 prize but the others are yet to be decided.

A New Mine-Taxing Movement has been inaugurated in Montana, with the special object of reaching the Anaconda Copper Mining Co. The latter, like most large and successful corporations, is constantly the subject of attack by would-be legislators, agitators and grafters of all grades. Under the present system of taxation, the mining companies pay only a small rate on their property, the big tax being collected on the personal property and the net earnings. Some years ago an attempt was made to tax the companies 3% additional on their gross earnings, but the movement was defeated. Now a law is being initiated to tax them 6% more, and is likely to obtain sufficient support to bring it before the voters of the state at the fall election. The charge is made that the movement was really inaugurated by antiprohibition forces to compel Anaconda to come out against prohibition or to put up money to fight the latter movement. For very good economic reasons the Anaconda company is not opposing the prohibition movement. It had an object lesson on the effect of prohibition during the military rule in Butte two years ago when the saloons were closed. During that period the efficiency of miners was increased 25% and accidents in the mines decreased about 90%. Against such a showing as that the big company could not declare itself opposed to prohibition by law. The hostility of the antiprohibitionists might therefore be expected.

DENVER—June 23

Alleged Claim-Jumping at Nederland was responsible for a recent disturbance in the tungsten field, in which gun plays and a hangman's noose figured. The sheriff has dispersed the "vigilance committees" that were organized in the district to discourage the practice.

American Smelting and Refining Co. has taken over the Green Mountain group in Cunningham Gulch, Silverton district. Under the superintendency of Charles Gardner, this property will be put into operating condition. The ore will be concentrated in the Silver Lake mill, and the products sent to the Durango smeltery. In the same district, the Hamlet mill, destroyed by fire last fall, is being replaced by a modern plant that will include flotation in its flowsheet.

Colorado School of Mines awarded scholarships this year to 34 graduates from high-schools within the state, these scholarships being acceptable by the school in lieu of all fees for four years. This is the first time the plan has been tried here. Prof. E. J. Dittus and H. W. Wright of the faculty are preparing a report for free distribution on the flotation research that has been conducted in the institution during the past year. The Denver branch of the U. S. Bureau of Mines is to move to the School of Mines, July 1, and thereafter will have its offices and laboratories in the Physics Building at Golden. The large testing plant will also be at the disposal of the Federal bureau.

Present Flow from Down-Town Mines at Leadville is about 1,700 gal. per min. at the bottom level; this is being easily handled by the electric-driven centrifugal sinking pump. Old reciprocating steam pumps are being removed and scrapped from this station to make room for the new electric pump of same design as the sinker but which will have a capacity of 2,000 gal. per min. After more than 13 months of steady pumping, the Down-Town Mines Co., of Leadville, has accomplished its purpose of draining the portion of the district lying within and adjoining the city limits. Through the efforts of Ex-Governor Jesse F. McDonald, an amalgamation of interests was effected between owners of more than 300 acres of valuable mining property and a magnificent pumping

plant established at the Penrose mine. Several of the levels are being driven anew while old ones are being cleaned out and put into shape for renewed productions.

Reduced Freight Rates on ore not exceeding $12 per ton in value have been established between Breckenridge to Denver. In the suit of the Wellington Mines Co. against the Colorado & Southern Railway Co. for a reduction of rates on zinc concentrates from the company's mills at Breckenridge, Colo., to Bartlesville and Collinsville, Okla., the Interstate Commerce Commission has denied the mining company reparation for freight charged on previous shipments, but has found that the increase from $1.50 to $3 per ton applicable from Breckenridge to Denver was not justified and has ordered the restoration of the through rate based on $2.25 component to Denver. The commission in its report states that the distance from Denver to Bartlesville via the Santa Fe is 725 mi., and that the through rate from Denver to Bartlesville, which was not in dispute and is also $2.25, earns for the railroad only 3.1 mills per ton-mile. The Wellington company testified that one of its mills was closed by reason of the increase in the Breckenridge-Denver freight rate and not by reason of any of its other troubles.

SALT LAKE CITY—June 23

The Smelting Plants in Salt Lake valley and vicinity have been working at capacity for some time, and have recently notified some of their shippers to curtail the output of certain low-grade ores.

A State Assay Office will be established at the University of Utah through the efforts of the state conservation commission. The plans have been tentatively approved by the U. S. Bureau of Mines and by the Salt Lake Chapter of the American Mining Congress. The object is to encourage prospecting to develop the mineral resources of the state. It is not intended to compete with regular assayers, and qualitative determinations but not quantitative analyses are to be made. This will enable prospectors and others to determine whether their finds are worth further investigation. When the plans have been worked out and approved a bulletin will be issued.

Utah Copper's New Leaching Plant will be begun within the next two or three weeks. The site has been selected, and plans are nearly completed. The initial capacity of the plant is to be 2,500 tons daily; and it will treat a large accumulation —40,000,000 tons or over—of oxide and carbonate ores, which occurred as a capping over the sulphide orebodies. This capping carries 0.5 to 1% copper. The Utah Copper Co. has for some time had an experimental plant in operation, and the results obtained will furnish the necessary data. Sulphuric acid, employed in the leaching, will be made at the plant of the Garfield Chemical and Manufacturing Co., now being erected near the Garfield smeltery.

Encouraging Results are being obtained at the Tintic Milling Co.'s plant at Silver City, and the company is planning an increase in capacity. At present, low-grade siliceous ore amounting to 100 tons daily is being treated, and preparations are being made to treble this amount. Holt-Dern roasters chiefly are being used, and six more of this type will be added. Excavation for their installation is in progress. Three clean-ups have been made thus far, each yielding about $24,000. The third lot amounted to about 20 tons of precipitates. The Iron Blossom and Dragon Consolidated are furnishing most of the ore at present, and the company has leases on a number of dumps in the district.

WALLACE, IDAHO—June 22

Dividends of Cœur d'Alene Mines for the first six months of 1916 established a new record, far in excess of the amount paid in any corresponding period in the history of the district. In the following detailed statement, except where stated as estimated, the figures are official. The estimates are conservative and it is probable that the actual figures are greater than here given: Federal, $240,000; Caledonia, $442,850; Bunker Hill & Sullivan, $797,500; Hecla, $650,000; Interstate-Callahan, $1,394,970; Success, $300,000; Hercules (estimated), $1,500,000; Green Hill-Cleveland (estimated), $400,000; Tamarack & Custer, $40,000; Hunter (estimated), $200,000; total, $5,965,320. The net earnings of Cœur d'Alene mines for the year 1915, as shown by sworn statements filed with the county assessor, amounted to $9,794,632. That is the highest record in the history of the district. Assuming that the same rate of production and profits will prevail during the last half of the year, 1916 will show an increase of at least one-third over the former high record.

JOPLIN—June 24

Cloudburst on June 19 flooded dozens of mines and curtailed production. Three miners were drowned at Coralbut mine at Chitwood. Galena camp was particularly hard hit, and some mines there will not be reopened for at least a month. unless special pumps are provided.

Calling Out of Militia has taken numerous men from local mines. Property hardest hit was the Coahuila at Duenweg. It's superintendent, C. D. Smith, is a major in the Missouri National Guard, and the assistant superintendent, Fred Nesbitt, is a captain. Both have gone with their regiment to the recruiting camp at Nevada.

Striking Hoistermen issued circular during week claiming 10 mines were paying scale of $5 per day demanded by Brotherhood of Hoisting Engineers. The following day all but one operator denied truth of this statement. No mines are now down through inability to get hoistermen. Average base price for blende during June will be about $78, or $10 less than May price, which will mean a 25c. reduction in wages for men, during coming month. Labor trouble not anticipated.

OATMAN, ARIZ.—June 22

The Stock-Market Slump is being felt in Oatman. Several prospects have been forced to shut down because of lack of funds to carry on development work. Unfortunately one or two of the best prospects in the district are included among the ones recently shut down. However, this condition will only be temporary as it is due entirely to the fact that many of the prospects depended upon Los Angeles "brokers" to raise the money for their development and it is a well-known fact that these brokers will haggle for an hour over a quarter of a cent a share on a 100-share lot of stock.

Revival of Mining in Cerbat Range is attracting considerable attention. The important developments at depth in the Tennessee and Golconda mines where commercial ore has been opened up at 1,400 ft. and 1,100 ft., is bringing this old mining country to the front again. The men who are coming into the district now realize that the day of shallow surface mining is past and only with the backing of large capital can successful mining be carried on. The complex sulphide ores, which were difficult to handle by other methods, have been brought into the commercial limelight by the development of the flotation process. It is interesting to note the entrance of the Guggenhein interests into this district through the optioning of the Elkhart mine, a famous old producer.

VIRGINIA, MINN.—June 23

Many Mines Are Closed on the Mesabi range as a result of the I. W. W. agitators continuing their campaign. At Eveleth the Oliver Iron Mining Co. has closed the underground operations at the Spruce, Fayal, Adams and Leonidas mines, though a few men are kept at work in the pit mines. Probably 800 men are affected at Eveleth. At Virginia, during a pitched battle a striking miner was shot and killed by a company guard. All saloons have been ordered closed. The closing of operations in the Virginia district affects at least 2,500 men. At Biwabik the business men have stopped credit to the striking miners. At Hibbing, on June 22, 1,500 striking miners paraded and at the meeting made the following demands: Abolishment of contract labor; minimum wage of $3 a day; 8-hr. shifts for every man; abolishment of Saturday night shift. The mines at Nashwauk and Buhl are operating as usual, no trouble having developed there to date. If miners do not return to work soon, the Oliver will probably close all its underground mines and only ship from openpits and stockpiles which can supply the furnace requirements.

IRON RIVER, MICH.—June 20.

Patriotic Spirit of Middle West has been generally misunderstood, having been misrepresented by the attitude of a few pacificists to whose views the daily press has given wide publicity. It is well, therefore, to note the attitude of a Michigan corporation here in connection with the Mexican crisis. The following notice was posted on June 19 at the four mines of the Munro Iron Mining Co. by G. L. Woodworth, manager of mines:

> Any employee of the Munro Iron Mining Co. who enlists in the army or navy or belongs to the militia of this nation, and is called to the service of this nation, will on his return receive his former position if he applies for same. Notify this office before leaving.

TORONTO—June 23

A Rush to Rice Lake Gold District is starting from Winnipeg and other points in Manitoba. Steamers will hereafter sail from Selkirk twice a week to accommodate miners and prospectors. A mining exchange will be opened in Winnipeg early in July to be known as the Manitoba Mining Exchange, at which Rice Lake and other stocks will be listed.

A Du Pont Powder Co. Subsidiary is being organized with $10,000,000 capital to operate exclusively in Canada. A water power and other properties on the Saguenay River in Quebec have been secured and the erection of a plant is expected to follow soon. It is stated that the plant will be utilized for the fixation of atmospheric nitrogen, which in due time will be applied to the manufacture of high explosives at the company's plants in the United States.

The Mining News

ALASKA

STRIKE reported in Innoko region on Boob and Mastodon creeks, tributaries of Ditna river, about 25 mi. from the gold discoveries.

NEW RUSH TO FOLEY CREEK, tributary of Notch Creek in Chisana district, resulted from work of McCallum brothers, Thomas McGeegin and Thomas McAllister. Find is about 20 mi. from Shushana and 23 mi. from Nabesna.

ALASKA GOLD BELT (Juneau)—Arthur Riendeau, who drove 2,500-ft. tunnel last year, will probably be awarded contract for new lower tunnel, in which lateral diamond drilling will also be done. Contracts will not be awarded until claim litigation is settled; decision expected soon.

ARIZONA

Cochise County

BUNKER HILL (Tombstone)—Several carloads copper ore, sampling above 16%, shipped by leasers from upper levels in old bonanza workings.

MASCOT (Dos Cabezas)—Copper-gold vein on the Oregon 100 level drifted on for 100 ft. and averages about 3 ft. wide; gold assays up to $71.40. On same level north crosscut exposed Off Incline oreshoot; 10 ft. wide, commercial copper ore. Diamond-drill hole P. 86 encountered chalcopyrite ore at 188 ft. and continued in ore 60 ft.; hole was drilled easterly from Drift 35 on the Consolidated level and is about 700 ft. below surface; disclosure considered important. John W. Prout, Jr., superintendent.

Maricopa County

SWALLOW (Wickenburg)—Situated in Castle Creek district, sold to J. P. Hutchinson, of El Paso; old 10-stamp mill in good condition; may operate soon.

RUSSIAN (Congress)—Acquired by C. H. Kunselman and J. W. Stacy, of Phoenix, who will develop; shaft in 10-ft. silver-gold orebody; drifting will start on 300-ft. (bottom) level.

Mohave County

MINNESOTA (Chloride)—Reorganized; unwatering started; about 25,000 gal. being pumped daily.

PAYROLL (Chloride)—Development temporarily stopped by water; being held in check by baler.

MIDNIGHT (Chloride)—Gus Holmes, Jr., and associates of Salt Lake City, sinking shaft 4 ft. per day with hand drills.

NORTH GEORGIA (Chloride)—Gus Holmes, Jr., is installing headframe and hoist to explore 75-ft. outcrop carrying silver and lead.

ELKHART (Chloride)—Bonded by American Smelting and Refining Co. and is being unwatered. Nearly 2 miles of workings; famous old lead-silver-zinc producer.

SILVER KEYSTONE (Chloride)—Adjoining old Keystone in Mineral Park section; will resume sinking to 300 ft. and connect with Keystone shaft. Headframe and hoist being installed.

TELLURIDE CHIEF (Kingman)—Shaft, down 45 ft., will be sent to 150-ft. point, from which drifts and crosscuts will be extended to tap Garnier and Big Swede veins. Latter stripped on surface for 52 ft.

KEYSTONE (Chloride)—This old mine in Mineral Park district now unwatered; developing oreshoot on 200-ft. level by hand drilling. Sinking 280-ft. shaft will be resumed after arrival of compressor and drills.

GOLD ORE (Goldroad)—Steadily sending 25 to 30 tons $20 ore to Gold Road mill; estimated 75,000 tons blocked out above 530-ft. level; shaft to be deepened 100 ft. and laterals extended. Pres. Werden states 30-ton mill contemplated.

LONGFELLOW (Chloride)—W. T. Smith, of New York, W. B. Twitchell, of Phœnix, and W. H. Crowell of Four Metals Co., Nogales, purchased Longfellow group from Hugh Wilson. The 140-ft. shaft, bottom of which is in 5-ft. gold-silver-lead-copper vein, will be unwatered.

TOM REED (Oatman)—Supt. E. M. Rabb states concerning recent strike on the 1,400-ft. level, that large body of milling-grade ore was found; reports that ore ran as high as $100 a ton were exaggerated. In regard to Black Eagle strike, an orebody running from $6 to $17 a ton, was opened lengthwise for about 300 ft. with tunnel, but no crosscuts have been run. Will sink shaft on claim, entirely surrounded by United Eastern ground.

Pima County

CORNELIA EXTENSION (Ajo)—Machinery ordered for sinking 500-ft. shaft.

SOUTH CORNELIA (Ajo)—Camp being established and work will begin soon on 500-ft. shaft.

COPPER MOUNTAIN (Ajo)—Drilling will be undertaken at once on this property, 18 mi. south of Ajo. Bonded recently by Julius Kruttschmidt, Jr., of Tucson, for American Smelting and Refining Co. E. J. Longyear Co. will do the drilling.

NEW CORNELIA (Cornelia)—New 10-in. water line from wells practically completed; machine shops in use and structural steel for crushing plant rapidly being put into place. Contract for 25 bungalows on townsite reported awarded to Otto Gröger, of El Paso.

BISBEE-AJO COPPER DEVELOPMENT CO. (Ajo)—New company formed in Bisbee to develop 24 claims, 22 mi. south of the Cornelia. Country rock schist and monzonite, impregnated with copper sulphides. Officers: John Sweeney, president; John Perry, vice-president; C. A. Johnson, secretary-treasurer.

Pinal County

ASBESTOS is being produced now in Gila County and in the Grand Cañon; lately, H. B. Riggs, S. E. Douglass and Philip Connelly of Mesa have had their claims near Superior inspected and another operation may result.

RAY CONSOLIDATED (Ray)—To guard against floods such as those of last spring, steel-concrete bulkheading is being placed along Mineral Creek at cost of $45,000.

Santa Cruz County

HARDSHELL (Patagonia)—Shipping lead ore to El Paso.

TRENCH (Patagonia)—Crosscutting from bottom of 500-ft. shaft.

BLUE EAGLE (Patagonia)—This claim in Alum Gulch optioned. Recently opened ore running 10% Cu and 10 oz. Ag.

HARRISON-SANDERS (Patagonia)—Compressor and machine drills being installed. Plan to sink another 100 ft. Last car shipped ran 9.2% Cu.

R. R. R. MINE (Patagonia)—Shipping 30 tons daily of 8% copper ore. Shipments will be increased. Ground broken June 20 for 100-ton unit of flotation plant.

DUQUESNE MINING AND REDUCTION (Duquesne)—Electric power now available at this property. Flotation plant being doubled. Shipping about three cars per week of high-grade copper ore.

Yavapai County

ARKANSAS & ARIZONA (Jerome)—Merger with Mowles Copper Co. ratified on June 12, 2,000,000, shares being paid Goodrich-Lockhart interests for Mowles property. Active development at both properties.

VERDE COMBINATION COPPER CO. (Jerome)—Formed by James M. Layman to prospect the Richards and other groups—about 500 acres—between United Verde Extension and Pittsburgh-Jerome. Peter Boyd, of National Tube Co., Pittsburgh, is president. A. P. Thompson, Jerome, in charge of development.

CALIFORNIA

Calaveras County

POORMAN (Altaville)—Drifting to tap rich gravel found in McElroy mine. Erickson & Nelson are leasers.

OZARK (Angels Camp)—Superintendent's dwelling completed and arrangements made for extensive work in this gravel mine.

ECONOMIC (Esmeralda)—Electrical equipment including transformers, motors and compressor received. Louis Robin in charge of installation.

Eldorado County

CEDARBURG (Georgetown)—Mine near Spanish Dry Diggings, idle for 35 years, is to be reopened.

BUNKER HILL (Greenwood)—Installation of machinery in progress at this copper mine near Penobscot. A 5-ton motor truck is to be used for hauling ore to Auburn. D. L. Shepherd, manager, has also bonded Argonaut mine, between Georgetown and Greenwood.

Modoc County

EL ORO (Lake City)—Gravel mine being opened under direction of Fred L. Phelps. Property will be developed by sinking to tap the channel. Hoisting and pumping machinery at railroad.

Nevada County

LEDUC (Grass Valley)—Crosscut in about 2,000 ft. and several veins cut, but the looked-for oreshoot not yet disclosed.

BOSS (North San Juan)—Reported that this property near Sweetland is to be reopened; formerly worked for gold but later disclosed copper deposit, at that time unprofitable, and mine was closed after shafts had been sunk 400 ft.

Plumas County

TAFT (Quincy)—Reported that option has been taken on this quartz property at Crescent Hill, owned by John Taft.

OVERSIGHT (Quincy)—John Wilson and August Benner will start their mill soon. Heavy snowfall gives assurance of plenty of water for power and milling.

PLUMAS GRASS VALLEY MINES CO. (Laporte)—Permitted to issue 50,000 shares, par $1, to net 80c. for development and 50,000 shares to J. F. Buel in exchange for an option to purchase Quigley placer claims of 100 acres for $21,000; $17,000 expended in development and equipment.

Santa Clara County

CHROME DEPOSITS, near New Almaden, discovered 40 yr. ago, purchased by F. L. Sage and R. B. Harper.

San Bernardino County

BISMUTH-ANTIMONY (Nipton)—Carload of 50% antimony ore shipped from this property on Clark Mountain, 20 mi. east.

TREASURY (Atolia)—This property, owned by M. H. Elliott, C. W. Peterson and D. V. McBridge, divided into 40 blocks about 200 feet square and leased; shipments being made.

Shasta County

AFTERTHOUGHT (Ingot)—Reported that American Metal Co. has relinquished option.

YANKEE JOHN DEVELOPMENT CO. (Redding)—Reorganization to succeed Yankee John Gold Mining Co. Controlled by Pittsburgh men and has been developed during the last 5 years.

SYBIL (French Gulch)—High-grade ore reported in this old mine on French Gulch Creek near the Milkmaid and Washington. The 5-stamp mill running at capacity. Joseph Day, leaser, killed on June 11 by explosion of gas ignited by his candle in 70-ft. shaft.

Sierra County

TWENTY-ONE (Alleghany)—Grading for millsite and boarding house.

EL DORADO (Alleghany)—Old producer bonded to L. Wagner and J. O'Brien.

SOVEREIGN (Sierra City)—Bonded to Mitchell & Bodfish, who will begin immediate operations.

ROCK CREEK (Downieville)—Tunnel in ore. Quartz mill to be installed. Dolan & Bell, owners and operators.

KATE HARDY AND DIADEM (Forest City)—Two richest mines in district under examination. Both mines equipped.

GRAY EAGLE (Downieville)—Bonded to Sidney C. Love and associates. Winze being sunk on ledge; mill and power plant ready; 13 men employed. G. L. Thomas, superintendent.

Siskiyou County

GOLD RUN (Yreka)—This old property, operated 40 yr. ago, is again said to be producing at a profit.

SISKIYOU SYNDICATE (Etna)—Operation resumed on Borden group, on Salmon River; 20-ton mill being installed. I. J. Luce is manager.

COLORADO

Chaffee County

COPPER ORE has been opened on Badger Creek, a few miles east of Salida.

Ouray County

IN RED MOUNTAIN DISTRICT, it is reported that James M. Hyde has taken option on the Crawford properties including Yankee Girl, Guston, Genessee, Vanderbilt and Treasury Tunnel, and will resume development work; mill is to be remodeled and flotation equipment installed.

San Juan County

TELESCOPE (Chattanooga)—Hübnerite vein opened. H. C. Fisher, manager.

KUNZ-AKERS (Eureka)—Being developed by R. E. L. Townsend and associates.

DORA CONSOLIDATED (Silverton)—Being reopened under management of L. C. Gillette.

GOLD KING (Gladstone)—Development and production will be resumed. Compressor plant repaired and mill is ready.

FAIRVIEW (Silverton)—High-grade gray-copper ore opened in the third-level north heading. George Bibb is manager.

CASCADE TUNGSTEN MINING CO. (Silverton)—Recently organized by Frank C. Grimes, George Haskell, A. M. Spears, W. A. Way and others.

RUBY (Silverton)—Pockets of hübnerite opened along outcrop of this 4-ft. vein for distance of 300 ft. Excavations being made for compressor plant and other buildings. Crosscut on the Wolfram property, being developed by C. Johnson and associates, opened Ruby vein west of main Ruby workings. Ore shipped to Yukon mill.

Teller County

MARY McKINNEY (Anaconda)—Strike of 3-oz. gold ore on bottom level.

DEXTER (Victor)—C. C. George electrocuted June 19 while installing electric hoist.

ELKTON (Elkton)—Main shaft timbered to Roosevelt Tunnel level and station there nearly finished. Nearly 2,500 tons of milling ore produced in June.

IDAHO

Jefferson County

WILBERT (Wilbert)—Report just issued shows milling in last fiscal year of 15,204 tons, assaying 25% Pb and 3.86 oz. Ag; concentrates averaged 52% Pb and 8 oz. Ag; contained 6,025,600 lb. lead and 46.419 oz. silver. Milling cost, $2.07 per ton. Oxidized tailings being tested for further treatment. Exploration in progress on 600 level.

Owyhee County

DE LAMAR (De Lamar)—This old mine leased by a syndicate, including J. B. Duncan, of Jordan Valley, Oregon.

Shoshone County

REX (Wallace)—Will commence work on tram and begin milling as soon as possible. Inclined winze, 1,130 ft. below surface, in ore, will be sunk 300 ft.

HYPOTHEEK (Kingston)—Important strike in east drift of 1,100 level, 15 in. of 75% lead ore and from 4 to 5 ft. of milling ore. Shoot opened for 400 ft. on 900 level. May increase 125-ton mill to 200 tons; shipments being made to Northport.

DOUGLAS (Kellogg)—Under bond to Anaconda company. Large body of zinc-lead ore developed in two tunnels; oreshoot in lower tunnel 850 ft. long, 3 ft. wide. Will install compressor and hoist and explore ground from shaft sunk 150 ft. from lower tunnel.

VIENNA-INTERNATIONAL (Wallace)—F. C. Bailey, of Spokane, and associates optioned 51% of stock and will install compressor and hoist. Property on Placer Creek, 6 mi. from Wallace in section now receiving much attention, but without productive mines. Shaft, 175 ft.; vein, 17 ft. wide with 3 ft. milling lead-silver ore.

MICHIGAN

Copper

LAKE (Lake Mine)—Grade of rock best in history; 19 drills at work.

HANCOCK (Hancock)—Increased shipments expected after July. One stamphead at Point Mills plant operating on rock from No. 2 shaft.

MOHAWK (Mohawk)—Refined output for May, 983,413 lb.; "mineral" output, 1,343,500 lb. from 50,156 tons of ore; discrepancy between "mineral" and refined larger than usual. Ore now coming mainly from Shafts 5 and 6; repair work in progress in northerly shafts, though operations resumed at No. 1 shaft.

Iron

ANTOINE ORE CO. (Iron Mountain)—Another stripping contract for removal of 50,000 cu.yd. awarded to John Marsch. Will bring pit close to shore of Lake Antoine.

HOLMES (Ishpeming)—Shaft down to 490 ft. Will go to about 1,200 ft.; first level will be at 950 ft. Permanent brick-and-concrete buildings being erected and machinery assembled. Headframe will be of steel, 130 ft. high. Shovels stripping to make stockpile room.

MINNESOTA

Mesabi Range

LAMBERTON (Hibbing)—Stripping now in progress should permit mining to begin by July 1. Pit will be 800x400 ft. Two shovels being used.

DEAN (Buhl)—Great slide of overburden recently; bank was 150 ft. high in places. Fifteen houses and large hall were damaged. Heavy rains caused slide.

KERR (Hibbing)—Mine, formerly known as the Sheridan, being reopened by Oliver Iron Mining Co. Overburden being dumped into Carson lake. Will ship about 500,000 tons this year.

MISSOURI-ARKANSAS

Joplin District

GIBSON (Joplin)—Field shaft opened 200 ft. north of mill. Bin capacity increased to 750 tons. Will produce three carloads of concentrates weekly.

ICE PLANT (Webb City)—Mill No. 2 just started by this company, though not completed. Is to have capacity of 1,000 tons in 24 hr. Sheet ground will be mined at 190 ft.

A. W. C. (Joplin)—Fourth mill started on Hercules tract; electrically operated; modern sludge unit with Dorr thickener. Four plants expected to produce 225 tons concentrates weekly.

VOGEY (Porto Rico)—American Zinc, Lead and Smelting Co., has taken additional 20-acre lease. Will open up Union shaft, unworked for nine years. Will build 500-ton bin and tram to Vogey mill, recently increased from 800 to 1,200 tons. The 2,700-cu.ft. compressor, largest in district, will furnish air for eight machines in Union workings. Small flotation plant now operating at Vogey; results not disclosed.

North Arkansas

EDITH (Rush)—Starting of mill delayed by collapse of bins.

MARION (Kingdom Springs)—Mill being erected on 640-acre tract.

OLD CONFEDERATE (Pindall)—Williams & Truitt reopened this lead mine, worked by Confederates during war.

MYRTLE (Rush)—P. W. Harley, of Oklahoma, has organized Shamrock company to operate this property on large scale.

MONTANA

Broadwater County

KEATING (Radersburg)—Extensive investigations being carried on as to best method of treating ores. Two shifts working and regular shipments being made.

CUSTER (Winston)—Contract for 100-ton mill let to Seattle firm. Mine was gold producer but has been tied up in litigation, now settled in favor of State Senator Charles H. Muffly, of Helena.

Lewis and Clark County

FRANKLIN (Helena)—Sulphide ore carrying gold discovered at 550 ft.

MARYSVILLE GOLD MINING CO. (Marysville)—Spokane tunnel will be driven over a mile to cut Blue Bird and Hickey veins in claims adjacent to Shannon mine. M. L. Hewett in charge.

Lincoln County

PROSPECTING of Libby Creek placers to be undertaken by San Francisco syndicate; area includes holdings of Libby and Comet companies, according to E. G. Mellander, of Libby. Gravel about 20 ft. deep; upper 10 ft. will not be washed.

Silver Bow County

BULLWHACKER (Butte)—East Butte will treat 100 tons of this company's ore daily, eliminating necessity of shipping to Tacoma and Salt Lake. Three carloads just shipped to the East Butte plant, showed 4.08, 4.10 and 4.14% Cu.

TUOLUMNE (Butte)—At the Butte Main Range and Colusa-Leonard properties in eastern section of district, company is retimbering Sinbad shaft; when unwatering is completed, development will begin on 500, 600 and 700 levels. Shaft sinking at Colusa-Leonard Extension will be started as soon as agreement submitted to stockholders is ratified.

BUTTE & BACORN (Butte)—Reorganization plans are proceeding satisfactorily. $264,000 required nearly subscribed. After debts are paid, working capital of $180,000 will be available. Company owns 278 acres of patented ground and option on 47 acres more. There are two shafts on property, 860 and 1,000 ft. deep. Properties about 3 mi. north of Anaconda mines.

BUTTE & SUPERIOR (Butte)—Report filed in Federal court, June 21, shows 50,688 tons of ore treated in May in flotation plant of company's mill at cost of $3.22 a ton; yielded 11,658 tons of concentrates valued at $65.25 a ton, as

against 50,112 tons of ore treated in April at cost of $2.84 per ton, to secure 12,080 tons of concentrates, valued at $83.79 per ton. This shows drop of $18.54 per ton in value of concentrates as well as drop in amount of concentrates secured and an increase in cost of treatment.

NORTH BUTTE (Butte)—Recent development between 600 and 800 levels near Speculator shaft, opened important orebodies in north and south branches of Sioux Chief vein. On 700 level vein was 7 to 11 ft. wide carrying 13% copper and 9 oz. silver per ton. On 800 level vein was over 6 ft. wide averaging 8% copper and 4.3 oz. silver per ton. In Berlin vein, 4 ft. of ore averaging 8.8% copper was opened. Granite Mountain shaft, now below 3,400 level, will be carried to 3,600 level, which will be deepest shaft in Butte. May output was 48,385 tons of ore, furnishing 2,000,000 lb. of copper and 89,000 oz. of silver. June output probably larger.

NEVADA

Esmeralda County

LONE STAR (Goldfield)—Controlling interest optioned to Eastern men who have resumed development.

GOLDFIELD ORO (Goldfield)—Shaft repairs completed to 700-ft. level. Will resume development on 800 level.

FLORENCE (Goldfield)—Enlargement of flotation plant from 150 to 300 tons per day delayed by nonarrival of machinery. Now expect increased capacity, middle of July.

LOUISIANA CONSOLIDATED (Tip Top)—Gold-silver property equipped with 10-stamp mill and cyanide plant. Reported that developments during winter exposed tonnage of $12 to $15 ore. Option taken on adjoining Brownie group. Plan to enlarge mill.

GOLDFIELD CONSOLIDATED (Goldfield)—New flotation equipment being rapidly assembled; should be in operation early in July with capacity of 1,000 tons per day; 48 Callow cells being installed. Will take run-of-mine feed; cyanide plant being utilized meanwhile for retreatment of old tailings. Tests covering several months in 50-ton flotation plant indicated 93% extraction, with reduction in present milling costs.

Humboldt County

ROCHESTER MINES CO. (Rochester)—Mill treating 115 tons per day; extraction about 92%. Costs first five months of 1916 were: Mining, $3.221; milling, $2.288; indirect, $0.827; total, $6.336. Ore reserves reported as "sufficient for several years' consumption" and "10,000 tons broken and stored in stopes."

Lincoln County

PIOCHE-BRISTOL (Pioche)—Three feet of high-grade silver-lead ore opened in Contact vein. Shipping will commence early in July. H. W. Parker, superintendent.

Nye County

TONOPAH ORE PRODUCTION for week ended June 17 was 8,937 tons, valued at $186,126, compared with 9,217 tons for week previous. Producers were: Tonopah Belmont, 2,748 tons; Tonopah Extension, 2,200; Tonopah Mining, 2,000; Jim Butler, 700; West End, 678; Halifax, 214; Rescue-Eula, 161; North Star, 58; miscellaneous, 178 tons.

TONOPAH MINING (Tonopah)—May profit was $26,330 from 9,239 dry tons, averaging $13.30 per ton.

JIM BUTLER (Tonopah)—In May, 3,153 tons were shipped to plant at Millers, yielding net operating profit of $23,360.

ROUND MOUNTAIN (Round Mountain)—From Mar. 9 to May 31, hydraulicked 106,600 yd. yielding about $40,000 in the sluices. Most of gold is on bedrock which has not been cleaned up.

WEST TONOPAH (Tonopah)—Idle since 1907; recently refinanced. Compressor and heavier hoist added to surface equipment; 850-ft. shaft repaired and will be sunk 400 ft. before undertaking lateral development.

TONOPAH BELMONT (Tonopah)—May profit amounted to $126,263, an increase of about $23,000 over April, due to high price of silver. During month 12,824 dry tons were treated, producing 2,363.75 oz. gold and 226,987 oz. silver.

TENNESSEE

STATE OF TENNESSEE has served notice on attorney general of Georgia of intention to file an intervention in U. S. Supreme Court in Georgia's case against Ducktown Copper Sulphur and Iron Co. Tennessee Copper Co.'s arrangement with State of Georgia expires in October.

UTAH

Beaver County

CROFT (Milford)—Shaft down 150 ft. and station will be cut and drifting started for ore opened above. R. R. Tanner, superintendent.

Juab County

PLUTUS (Eureka)—Reported operations will be resumed through the Chief.

D & B MINES (Eureka)—Incorporated to work 60 claims in north Tintic. Gold ore opened. Salt Lake and Tintic men interested.

MAMMOTH (Eureka)—One or two cars of 17% copper ore being shipped monthly from 600 level. Mine has been shipping about 4,000 tons monthly but owing to lack of demand for certain kinds of ore, shipments will be cut to 2,500 tons.

GEMINI (Eureka)—Shipments resumed after two weeks' halt in underground work following accident to cage and cable. Loading station at new railroad spur completed and it is now possible to ship both via the Rio Grande and the Salt Lake route.

Salt Lake County

MICHIGAN-UTAH (Alta)—Further lead ore opened in Copper Prince tunnel.

SOUTH HECLA (Alta)—New strike, made 800 ft. from surface, shows 10 to 12 ft. of shipping ore.

UTAH COPPER (Bingham)—About 20 steam shovels are in operation, handling about 30,000 tons daily, exclusive of waste.

GREAT DIVIDE MINES (Bingham)—Special meeting July 8 to consider proposed bond issue to pay debts and furnish working capital. E. D. Haskins, secretary.

UTAH METAL AND TUNNEL (Bingham)—Much development being done. Orebody, opened on 850 level of New Haven, being followed easterly-westerly and on dip. Malloy bedding reached by a raise, giving 200 ft. of new stoping ground; ore is about 4 ft. thick. Mill capacity increased from 125 to over 225 tons.

Summit County

DALY (Park City)—Work being done on company account and by about 40 lessees.

BROADWATER MILLS, Big Four, Beggs and smaller mills are operating. Another mill to treat tailings just completed by Charles Moore on flat below Park City near Homer ranch; capacity, 75 tons a day.

Tooele County

O. K. SILVER (Indian Springs)—Second car of high-grade silver ore shipped.

VIRGINIA

Rockingham County

U. S. MANGANESE CORPORATION (Elkton)—This company has taken over the old Kendall & Flick manganese mines and additional property comprising about 1,000 acres; numerous old shafts on properties, and considerable good ore has been shipped in the past. Company reports 13 drill holes put down, showing good manganese orebodies. Three shafts being sunk, depths from 80 to 150 ft. Capt. C. J. Bartels, superintendent; W. F. G. Berger, consulting engineer. It is expected that arrangements will be made with the newly formed Seaboard Steel and Manganese Corporation, for manufacture of ferro-manganese at old Reading furnace at Temple, Penn. This furnace has a pig-iron capacity of 175 to 200 tons per day. New York office, 74 Broadway.

CANADA

British Columbia

GRANBY (Vancouver)—May output, 4,727,929 lb. copper of which over 3,383,230 lb. was produced at Anyox where four furnaces are in operation.

Ontario

COBALT ORE SHIPMENTS over Temiskaming & Northern Ontario Ry., in May were: Beaver, 16.62 short tons; Buffalo, 31.28; Cobalt Comet, 54.75; Coniagas, 110.83; Crown Reserve 103.61; Kerr Lake, 113.50; La Rose, 96.02; McKinley Darragh, 333.34; Mining Corporation of Canada, Cobalt Lake, 117.93, Townsite-City, 41.14; Nipissing, 64.69; O'Brien, 42.99; Penn Canadian, 76.45; Peterson Lake, 41.77; Right-of-Way, 46.58; Temiskaming, 68.44; total, Cobalt proper, 1,359.94 tons; Casey-Cobalt (New Liskeard), 29.02; Miller Lake-O'Brien (Elk Lake), 20; total silver-ore shipments, 1,408.96 tons; Copper ore, Rand Syndicate (Temagami) 34 tons. Nickel ore, Alexo (Pourquois Junction) 959 tons.

DAVIDSON (Porcupine)—Mine being reopened.

TEMISKAMING (Cobalt)—Station cut at 1,100-ft. level.

NIPISSING (Cobalt)—Refinery damaged by fire, June 21; loss small.

FOLEY O'BRIEN (Porcupine)—Expected to resume about middle of July.

GENESSEE—Cut 2-in. vein at 150 ft. on claim adjoining the Chambers-Ferland.

SCHUMACHER (Porcupine)—May production was $20,908; total operating expenses, $15,128, or $3.58 a ton.

LAKE SHORE (Kirkland Lake)—High-grade ore struck on 300-ft. level, the vein extending into the Teck Hughes.

PETERSON LAKE (Cobalt)—A 2-in. vein carrying native silver opened on the Reliance claims on which company has option.

BOSTON CREEK GOLD MINES (Boston Creek)—New $2,500,000 company to take over Kenzie and about 50 claims owned by R. A. P. Syndicate.

NATIONAL (Cobalt)—This company, leasing on the King Edward, has sunk to 700-ft. level, and will continue shaft 350 ft. further to reach lower contact.

CROWN RESERVE (Cobalt)—A 12-in. shoot, recently found at 700-ft. level, carries leaf silver and will average 500 oz. per ton. Vein is in the Keewatin and 200 ft. below any ore previously found. Work on the Cochrane proceeding but option on McCrea group at Boston Creek has been dropped.

DOMINION RAND SYNDICATE (Temagami)—On these claims near Temagami Lake, large body of chalcopyrite ore, 60 ft. wide in one place, has been found. Three carloads shipped. Aërial tramway being installed to convey ore 1,000 ft. from mine to lake; then transported on scows to Temagami station.

MEXICO

IN EL ORO DISTRICT, Esperanza and Dos Estrellas companies resumed crushing in May at rate of 400 and 600 tons per day, respectively. Letter, dated June 7, stated El Oro and Mexico Mines of El Oro were to resume "in near future."

BOLIVIA

SINDICATO PETROLIFERO DEL ORIENTE BOLIVIANO is title of syndicate formed by Luis Lavadenz and other Chileans to explore 545,000 hectares of petroleum-bearing lands in Department of Santa Cruz, Province of Cordillera. Engineering party left Cordova for fields early in June.

SOUTH AMERICAN ELECTRIC SMELTING CO. (Pittsburgh, Penn., U. S. A.)—R. S. Wile and L. H. Lee of Wile Electric Furnace Co., sailed from New York June 14 to erect electric furnace for smelting Bolivian tin ore.

CHOSEN

ORIENTAL CONSOLIDATED (Unsan)—In April, 200 stamps ran 28¼ days; crushed 26,142 tons; yield $146,062; operating costs $77,720; construction $1,869; net profits $66,472.

The Market Report

Metal Markets

NEW YORK—June 28

Again we have to chronicle a week of dullness and reactionary tendencies, but as was the case at the time of our last report, lead was the exception. That metal has continued to exhibit a firmness and volume of business superior to any other metal.

Copper, Tin, Lead and Zinc

Copper—This market was again very dull and the volume of business reported was much less than in the previous week, small as it was then. The principal producers are entirely out of touch with the market, being thoroughly sold up for months to come, and indifferent to temporary recessions. The primary market at present, as during recent weeks, is in the hands of the smaller producers and the trading agencies, who being desirous of selling copper, accept what they can get. They are able to furnish plenty of July and July-August copper to meet the present small demand. In the early part of the week, July copper was reported sold at 26c., cash, New York, and in the latter part of the week, July at 25¾c., July-August at 25½c., while August-September was offered in round lots at 25¼c. During several days no transactions at all were reported, and quotations were but nominal.

Exports from Baltimore for the week included 168,242 lb. copper to Liverpool; 5,103,414 lb. copper to Havre, France; making 5,271,656 lb. in all.

Copper Sheets are unchanged at 37.5c. for hot rolled and 38.5c. for cold rolled. Copper wire is 31½@32c. per lb. for large lots at mill.

Tin—This market fluctuated in sympathy with the London market. It was dull, draggy and weak.

Lead—The same curious condition noted in several weeks lately, viz., some of the producers reporting good business and others reporting not much inquiry coming their way, continued to exist. Putting all reports together, the aggregate volume of business was larger than in the previous week. There was some export business done and there was substantial buying by domestic consumers. The nature of the orders of some of the latter indicated that they had allowed their stocks to run low. On the other hand, the statistical position from the standpoint of the producers is remarkably strong. There is no one of them who is carrying over from month to month any stock than is larger than ordinary business precaution requires to be on hand, and in some cases it is probably below the safety limit. Prices realized during the last week were rather irregular.

Spelter—Scarcely any sales of consequence were reported, and the market is quoted nominally on the offers to sell. Prices crumbled away almost from day to day, without there being any strong pressure to sell. The large producers apparently realize that it would be futile to attempt to sell any large quantities at present, but the smaller producers make offerings. There is now plenty of spelter available for early delivery, and there is no doubt that stocks are beginning to accumulate. At the close, prompt spelter was offered at 11¼c., July at 11c. and August at 10¾. July-August contracts were offered at 11c., and July-September at 10¾c. Spelter for delivery in the last quarter was offered at 10 cents.

Zinc Sheets are again easier. The base price was reduced on June 27 to $18 per 100 lb., f.o.b. Peru, Ill., less 8% discount.

Other Metals

NEW YORK—June 28

Aluminum—The market continues active, and there is not much metal offered outside of contract business. Quotations are 62@64c. per lb. for No. 1 ingots, New York.

Antimony—This market was extremely dull and hollow. We quote spot antimony nominally at 17½@18c., but if any orders should come in sight the competition for them would be so keen that without any doubt the price would be cut sharply. None of the important antimony interests was willing to quote on shipments from China.

Quicksilver—This market was more active, the turn in prices having brought in consumers as buyers. The New York market is quoted at $78 per flask, while San Francisco reports by telegraph $80 per flash, market strong. The London price is unchanged at £16 10s. per flask.

Nickel—The market continues steady with about the same amount of domestic business as usual and with some demand for export. Quotations are 45@50c. per lb. for ordinary forms, according to size and terms of order. Electrolytic nickel brings 5c. per lb. premium.

Minor Metals—Current quotations for **Bismuth** are $3.15@3.30 per lb., New York—**Cadmium** is quoted at $1.30@1.50 per lb.—**Cerium,** electrolytic, is sold at $8@9 per lb.

DAILY PRICES OF METALS IN NEW YORK

June	Sterling Exchange	Silver, Cts. per Oz.	Copper: Electrolytic, Cts. per Lb.	Tin: Spot, Cts. per Lb.	Lead: New York, Cts. per Lb.	Lead: St. Louis, Cts. per Lb.	Zinc: St. Louis, Cts. per Lb.
22	4.7575	65	26 @26¼	39¾	6.85 @7.00	6.65 @6.75	11.00 @11.75
23	4.7575	65⅜	25¾ @26¼	40¼	6.80 @7.00	6.55 @6.75	11.00 @11.75
24	4.7575	66⅛	25¾ @26	40¼	6.75 @7.00	6.50 @6.75	11.00 @11.50
26	4.7575	65¾	25¼ @25¾	39½	6.80 @7.00	6.62½ @6.75	11.00 @11.50
27	4.7575	66	25¼ @25¾	39	6.80 @7.00	6.62½ @6.75	10.75 @11.25
28	4.7575	66¼	25¼ @25¼	39¼	6.80 @7.00	6.62½ @6.75	10.75 @11.25

The quotations herein are our appraisal of the average markets for copper, lead, spelter and tin based on wholesale contracts for the ordinary deliveries of the trade as made by producers and agencies; and represent, to the best of our judgment, the prevailing values of the metals, reduced to basis of New York, cash, except where St. Louis is given as the basing point. St. Louis and New York are normally quoted 0.17c. apart.

The quotations for electrolytic copper are for cakes, ingots and wirebars. Electrolytic copper is commonly sold at prices including delivery to the consumers and is subject to discounts, etc. The price quoted for copper on "regular terms" (r.t.) is the gross price including freight to the buyer's works and is subject to a discount for cash. The difference between the price delivered and the New York cash equivalent is at present about 0.25c. on domestic business. The price of electrolytic cathodes is 0.05 to 0.10c. below that of electrolytic. Quotations for lead represent wholesale transactions in the open market for good ordinary brands. Quotations for spelter are for ordinary Prime Western brands. Only the St. Louis price is herein quoted, St. Louis being the basing market. We quote the New York price at 17c. per 100 lb. above the St. Louis price.

Silver quotations are as reported by Handy & Harman and are in cents per troy ounce of silver bars 999 fine.

Some current freight rates on metals per 100 lb. are: St. Louis-New York 17c.; St. Louis-Chicago, 6.3c.; St. Louis-Pittsburgh, 13.1c.

LONDON

June	Silver	Copper: Standard Spot	Copper: Standard 3 Mos.	Copper: Electrolytic £ per Ton	Copper: Electrolytic Cts. per Lb.	Tin: Spot	Tin: 3 Mos.	Lead: £ per Ton	Lead: Cts. per Lb.	Zinc: £ per Ton	Zinc: Cts. per Lb.
22	31	97	95	133	28.32	172¼	172¾	30	6.38	67	14.27
23	31 5/16	98	96	130	27.68	175¼	176¼	29½	6.28	66	14.05
24	31 5/16	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
26	31⅛	102	99	130	27.68	173¼	173¼	29¾	6.33	65	13.83
27	31⅛	102	98	130	27.68	171½	172	29¾	6.33	65	13.83
28	31⅛	103	100	130	27.68	172	172½	29	6.17	63	13.41

The above table gives the closing quotations on London Metal Exchange. All prices are in pounds sterling per ton of 2,240 lb., except silver which is in pence per troy ounce of sterling silver, 0.925 fine. Copper quotations are for standard copper, spot and three months, and for electrolytic, price for the latter being subject to 3 per cent. discount. For convenience in comparison of London prices, in pounds sterling per 2,240 lb., with American prices in cents per pound the following approximate ratios are given, reckoning exchange at 4.80. £15 = 3.21c.; £20 = 4.29c.; £30 = 6.43c.; £40 = 8.57c.; £60 = 12.85c. Variations, £1 = 0.21⅜c.

Gold, Silver and Platinum

NEW YORK—June 28

Gold—More gold has come to New York from Canada. Some has also been received direct from London. The total amount is approaching $100,000,000 on this movement.

The Russian government has ordered a premium paid on all gold deposited at the official assay offices and banks. The object is to stop illegal exports from Siberia by merchants and traders.

Platinum—The market continues very slow. Transactions are necessarily limited by small supplies, and buyers are taking only what is necessary. Quotations are $75@78 per oz. for refined platinum.

Our Russian correspondent writes that there has been some revival in activity. The price has been kept down, notwithstanding a better demand, by government sales, the quantity requisitioned some time ago having proved greater than was needed. Moreover the high prices have stimulated production and more metal is offered. Producers are stiff, believing that prices will not fall below present level. Quotations for crude metal, 83% platinum, are 17 rubles per zolotnik—$63.92 per oz.—at Ekaterinburg, and 65,000 rubles per pood—$63.70 per oz.—at Petrograd.

Silver—The market has rested fairly steady the past week between 31 and 31⅝d. in London. The combination of buyers in London is tending toward steadiness in price. The possibility of war with Mexico is also a bullish factor but has had no effect on prices as yet. Mexican supply would undoubtedly be curtailed in case of hostilities. Coinage demand abroad still continues, with shipments from Shanghai to Bombay for the Indian Government.

On June 22 Mexican dollars in New York were quoted at 50@55c.; June 23 at 50¼@55¼c.; June 24, at 50⅞@53⅞c.; June 26, at 50⅝@53⅞c.; June 27, at 50⅞@54c.; June 28 at 51@54⅛c., closing.

Zinc and Lead Ore Markets

PLATTEVILLE, WIS.—June 24

The base price paid this week for zinc ore was $75@77 per ton 60% zinc for top grades down to $70 base for medium grades assaying down to 50% zinc. The base price paid for 80% lead was $78@80 per ton.

SHIPMENTS, WEEK ENDED JUNE 24

	Zinc Ore, Lb.	Lead Ore, Lb.	Sulphur Ore, Lb.
Week	5,316,000	225,780	610,800
Year	113,840,000	4,147,710	28,147,400

Shipped during week to separating plants, 7,520,000 lb. zinc ore.

JOPLIN, MO.—June 24

Blende, high price $92.90; premium ore, per ton 60% zinc, $90; medium $86@75; low $70; calamine, per ton 40% zinc, $60@50; average, all grades of zinc, $78.83 per ton. Lead, high price, $82.25; base $80@77.50 per ton 80% metal content; average selling price, $80.57 per ton; the bulk of ore selling on the lower base was purchased for next week's delivery.

SHIPMENTS WEEK ENDED JUNE 24

	Blende	Calamine	Lead	Values
Totals this week..	11,454,930	940,930	2,721,710	$598,200
Totals this year...	346,749,930	28,510,830	59,271,340	$21,785,340

Blende value, the week, $463,120; 25 weeks, $18,086,460.
Calamine value, the week, $25,460; 25 weeks, $1,025,000.
Lead value, the week, $109,620; 25 weeks, $2,673,880.

The portion of the mining district immediately surrounding Joplin was partly disabled a couple of days this week by a waterspout, or rainfall of over 5 in. in two hours, early Monday morning.

OTHER ORES

Manganese Ore imports into the United States in April were 48,413 gross tons, against 218 tons in April, 1915. For the four months ended Apr. 30 the total imports were, 10,492 tons in 1915, and 99,958 tons in 1916; increase, 89,466 tons.

Imports of manganese ore in Great Britain five months ended May 31 were 107,297 tons in 1915, and 174,666 in 1916; increase, 67,369 tons.

Imports at Baltimore for the week included 1,760 tons of manganese ore from Brazil.

Antimony Ore—There is not much demand. On the other hand there is very little for sale, imports being held back by high freight rates. Quotations are nominal at $2 per unit.

Tungsten Ore—More inquiry is reported, especially as buyers are getting ready to contract for their second-half requirements. No business is reported, however, except a few small sales at $30@32 per unit. Holders are asking $35@40 per unit, with no sales.

Iron Trade Review

PITTSBURGH—June 27

Prospects of war have not been affecting the steel market materially in the past few days, and for one reason because there was so very little to affect, the domestic steel market being extremely dull. Export demand from neutral countries continues particularly heavy, as it has been for more than a month.

The strike in the Pittsburgh coal district is practically over, many men having returned to work yesterday and today, and the coal market has become nominal.

Pig Iron—The low prices at which warrants for Southern iron have been dumped on the market by speculators has adversely affected sentiment. We continue to quote: Bessemer, $21; basic, foundry and malleable, $18.25@18.50; forge, $18, f.o.b. Valley furnaces, 95c. higher delivered Pittsburgh.

Steel—The open market is quiet and prices are hardly as firm, though they are not quotably lower, being about $40@42 for bessemer and $40@45 for openhearth, with rods $55@60 and forging billets $65@70 per ton.

FERROALLOYS

Spiegeleisen is quoted $50@55 per ton for 20% at mill. For higher grade, 25 to 30%, about $5 more is asked. Supplies are a little better.

Ferrosilicon is nominally held at $83@85 per ton at mill for 50%; but premiums are paid for early delivery. Bessemer ferrosilicon is from $33 per ton for 10% up to $43 for 16%, at mill.

Ferromanganese—The market is excessively dull. Prompt may still be quoted at $225@250 but there is little being done to establish the figures. Contract remains at $175, for next year's delivery.

Imports of Ferromanganese in May are reported by the Department of Commerce as follows: At Baltimore, 6,195; Philadelphia, 1,198; New Orleans, 1,073; total 8,466 gross tons.

Imports at Baltimore for the week included 2,280 tons ferromanganese from Liverpool.

IRON ORE

Imports and Exports of Iron Ore in the United States four months ended Apr. 30, in gross tons:

	1915	1916	Changes
Imports	334,02?	353,254	I. 19,232
Exports	9,.38	25,575	I. 16,337

Of the imports this year 210,576 tons, or nearly 60%, were from Cuba. The exports are nearly all to Canada, from the Lake Superior ports.

COKE

Coke production in the Connellsville region for the week is reported by the "Courier" at 433,476 net tons; shipments, 433,630 tons. Upper Connellsville and Greensburg district shipments, 32,781 tons.

Coal and Coke on Pennsylvania R.R. lines east of Pittsburgh and Erie five months ended May 31, short tons:

	1915	1916	Changes
Anthracite	4,580,414	4,952,149	I. 371,735
Bituminous	16,597,074	20,524,490	I. 3,927,416
Coke	4,008,443	6,162,191	I. 2,153,748
Totals	25,185,931	31,638,830	I. 6,452,899

The total gain this year was 25.6%. The largest proportional gain—53.7%—was in coke. May tonnage was 6,112,581 tons, an increase of 874,077 tons, or 14.3% over May of last year.

Chemicals

NEW YORK—June 28

The general market is rather inclined to be quiet and business has been only on a moderate scale.

Arsenic—On a moderate business prices continue at $6@6.50 per 100 lb. for spot, and $6 for futures.

Copper Sulphate—The tendency of the market has been downward. Sales are reported at $10@12 per 100 lb. for carload lots.

Nitrate of Soda—The market has been depressed by reports of heavy production and shipments. Quotations are easier at $3.05@3.10 per 100 lb. for both spot and futures.

Pyrites—Imports at Baltimore for the past week included 7,645 tons pyrites from Huelva, Spain.

Assessments

Company	Delinq.	Sale	Amt.
Advance, Mont.	June 15	July 15	$0.005
Algomah, Mich.	May 18	.....	1.00
Blue Bell, Ida.	July 8	Aug. 5	0.002
Bullion, Ida.	July 10	July 31	0.01
Cedar Creek, Ida.	July 5	Aug. 5	0.01
Central Eureka, Calif.	June 16	July 14	0.05
Challenge, Nev.	June 12	July 7	0.05
Columbus Ext., Utah	July 13	Aug. 8	0.02
Confidence, Nev.	June 23	July 14	0.10
Cons. Imperial, Nev.	July 18	Aug. 10	0.01
Crackerjack, Nev	July 3	Aug. 1	0.01
East Hercules Ext., Ida.	May 1	July 3	0.0015
Emerald, Utah.	June 15	July 8	0.0033
Fortuna, Utah	June 15	July 8	0.005
Friend, Ida.	June 30	July 20	0.002
Giant, Ida.	June 16	July 17	0.003
Goldstrike Bon., Utah	June 15	July 15	0.01
Gold Mt. Champion, Utah	July 20	Aug. 10	0.0025
Gould & Curry, Nev.	July 14	Aug. 3	0.03
Hope, Calif.	July 17	Aug. 14	0.01
Imperial, Ida.	June 12	July 12	0.005
Independence, Ida.	July 8	July 29	0.001
Laclede, Ida.	July 3	July 25	0.003
Leonora, Utah	June 20	July 11	0.005
National, Ida.	June 2	July 3	0.02
Nevada-Douglas, Nev.	July 15	Aug. 16	0.10
North Franklin, Ida.	June 19	July 8	0.005
North Lake, Mich.	June 14	.....	1.00
Old Veteran, Ida.	July 8	Aug. 5	0.002
Ophir, Nev.	June 13	July 6	0.05
Rio Grande, Nev.	June 22	July 22	0.002
Rob Roy, Ida.	June 10	July 10	0.002
Rockford, Ida.	June 30	July 21	0.002
Sierra Nevada, Nev.	July 11	Aug. 3	0.10
Silver Moon, Ida.	July 8	Aug. 3	0.005
Silver Pick, Nev.	July 5	Aug. 14	0.01
Spearhead Reor., Nev.	July 3	Aug. 3	0.01
Swansea Ext., Utah	July 10	Aug. 1	0.0025
Ton. Gypsy Queen, Nev.	July 11	Aug. 15	0.01
Uvada, Nev.	June 24	July 27	0.02
Wallace, Ida.	June 29	July 29	0.0025
Wasatch-Utah, Utah	June 19	July 22	0.0025
Wisconsin North Fork, Calif.	June 12	July 10	0.01

Stock Quotations

SAN FRANCISCO June 27	
Name of Comp.	Bid.
Alta	.05
Andes	.14
Best & Belcher	.05
Bullion	.03
Caledonia	.40
Challenge Con.	.09
Confidence	.23
Cons. Imperial	.01
Con. Virginia	.10
Gould & Curry	.02
Hale & Norcross	.08
Jacket-Cr. Pt.	.05
Mexican	.15
Occidental	.70
Ophir	.27
Overman	.08
Savage	.07
Seg Belcher	.02
Sierra Nevada	.23
Union Con.	.72
Utah Con.	.01
Belmont	4.00
Jim Butler	.87
MacNamara	.06
Midway	.21
Mont.-Tonopah	.26
North Star	.15
Rescue Eula	.31
West End Con.	.90
Atlanta	.10
Blue Bell	.01
Booth	.15
C.O.D. Con	.03
Comb. Frac	.07
D'field B.B.	.02
D'field Daisy	.C2
Jumbo Extension	.77
Pitts.-Silver Peak	.09
Round Mountain	.60
Sandstorm Kendall	.04
Silver Pick	.09
Central Eureka	.11
Argo	.15
Big Jim	.87½
Lazy Boy	.15
Oatman Cres.	‡.42
Oatman No. Star	.20
Tom Reed	1.45
United Eastern	3.75
United Western	.13

LONDON June 14			
Alaska Tre'dwell	£6	7s	6d
Burma Corp.	2	13	1½
Cam & Motor	0	15	0
Camp Bird	0	9	9
El Oro	0	10	3
Esperanza	0	11	6
Mexico Mines	4	2	6
Nechi, pfd.	0	13	6
Oroville	0	16	0
Santa Gert'dis.	0	14	9
Tomboy	1	3	3

SALT LAKE June 27	
Name of Comp.	Bid.
Alta Con.	.49
Black Jack	.05½
Colorado Mining	.10½
Crown Point	.04
Daly-Judge	7.40
Emma Cop.	.44
Gold Chain	.25½
Grand Central	.69
Iron Blossom	1.60
Lower Mammoth	.04
May Day	.12
Opohongo	.01½
Prince Con.	1.30
Seven Troughs	.02½
Silver King Coal'n	2.60
Silver King Con.	3.07½
Sioux Con.	.10½
Uncle Sam	.06
Yankee	.20½

COLO. SPRINGS June 27	
Acacia	.03½
Doctor Jack Pot	.09
Elkton Con.	.15
El Paso	.77
Findlay	.03½
Gold Sovereign	.03½
Golden Cycle	2.12
Granite	.65
Isabella	.16½
Jack Pot	.05
Jerry Johnson	.04
Mary McKinney	.35
Portland	1.65
Vindicator	2.25

TORONTO June 27	
Adanac	.80
Bailey	.07
Chambers Ferland	.22
Coniagas	5.00
La Rose	.61
Peterson Lake	.24
Right of Way	.05
Seneca Superior	.35
T. & Hudson Bay	50.00
Temiskaming	.62
Trethewey	.23
Wettlaufer-Lo	.09
Dome Exten.	.35
Dome Lake	.33
Foley O'Brien	.48
Hollinger	29.50
Imperial	‡.03
Jupiter	.32½
McIntyre	1.55
Porcu. Crown	.75
Preston E. D.	‡.03
Vipond	.55
West Dome	.35

N. Y. EXCH. June 27	
Name of Comp.	Clg.
Alaska Gold M.	19½
Alas'a Juneau	8½
Am.Sm.&Ref.,com.	92½
Am. Sm. & Ref., pf.	111
Am. Sm. Sec., pf. A	92
Am. Sm. Sec., pf. B.	84
Am. Zinc	40½
Am. Zinc, pf.	65
Anaconda	79½
Batopilas Min.	1½
Bethlehem Steel	440
Bethlehem Steel, pf.	130
Butte & Superior	66½
Chile Cop.	20½
Chino	48½
Colo. Fuel & Iron	41
Crucible Steel	75½
Dome Mines	25½
Federal M. & S.	12½
Federal M. & S., pf.	35½
Great Nor., ore ctf.	34
Greene Cananea	37
Homestake	130
Inspiration Con.	49
International Nickel	45½
Kennecott	47½
Lackawanna Steel	66
Miami Copper	34½
Nat'l Lead, com.	65
National Lead, pf.	113
Nev. Consol.	16½
Ontario Min.	6½
Quicksilver	2½
Quicksilver, pf.	4½
Ray Con.	21
Republic I&S, com.	43
Republic I&S, pf.	107
Sloss-Sheffield	47
Sloss-Sheffield, pf.	93
Tennessee Copper	34
Utah Copper	76½
U. S. Steel, com.	83½
U. S. Steel, pf.	117½
Va. Iron C. & C.	48

N. Y. CURB June 27	
Beaver Con.	.40
Buffalo Mines	1
Butte & N. Y.	5½
Butte C. & Z.	4½
Can. Cop. Corpn.	1 13/16
Cashboy	.07
Cerro de Pasco	34½
Con. Ariz. Sm.	1½
Con. Copperminesc.	2½
Con. Nev.-Utah	.28½
Crystal Cop.	1
First Nat. Cop.	3½
Florence	.40
Goldfield Con.	.82
Goldfield Merger	.08
Granite	.38
Hecla Min.	5 5/16
Howe Sound	4½
Jerome Verde	1½
Joplin Ore & Spel.	2½
Kenefick Zinc	‡13½
Kerr Lake	4½
Magma	14½
Majestic	.50
McKinley-Dar-Sa.	.50
Mines of Am.	2½
Mother Lode	.27
Nevada Hills	.18
N. Y. & Hond.	15½
Nipissing Mines	7½
Oro	.05
Ray Hercules	3½
Rochester Mines	.17
St. Joseph Lead	16
Standard S. L.	1½
Stewart	.25
Success	.80
Tonopah	6
Tonopah Ex.	5½
Tribullion	7/16
White Knob, pf.	1½
Yukon Gold	2

BOSTON EXCH June 27	
Name of Comp.	Bid
Adventure	2
Ahmeek	93½
Algomah	1½
Alloues	64½
Ariz. Com., ctfs.	8½
Bonanza	.25
Butte-Balaklava	2
Calumet & Ariz.	67
Calumet & Hecla	525
Centennial	15½
Copper Range	59
Daly West	2½
East Butte	11½
Franklin	6½
Granby	85
Hancock	10
Hedley	‡20
Helvetia	.25
Indiana	2½
Island Cr'k, com.	47
Island Cr'k, pfd.	88½
Isle Royale	27½
Keweenaw	4
Lake	11
La Salle	3½
Mason Valley	2½
Mass.	11½
Mayflower	2
Michigan	2½
Mohawk	97½
New Arcadian	6
New Idria	13
North Butte	21
North Lake	1½
Ojibway	1
Old Colony	1½
Old Dominion	65
Osceola	90
Quincy	86
St. Mary's M. L.	73
Santa Fe	1½
Shannon	8
Shattuck-Ariz.	28½
So. Lake	6
So. Utah	.15
Superior	14
Superior & Bost.	3½
Tamarack	44
Trinity	5½
Tuolumne	.40
U. S. Smelting	65½
U. S. Smelt'g, pf.	50½
Utah Apex	4 1/16
Utah Con.	12½
Utah Metal	7½
Victoria	2½
Winona	5½
Wolverine	54½
Wyandot	1½

BOSTON CURB June 27	
Bingham Mines	10½
Boston Ely	.60
Boston & Mont.	.85
Butte & Lon'n Dev.	.69
Calaveras	4½
Calumet-Corbin	.04
Chief Con.	1 1/16
Cortez	.40
Crown Reserve	.51
Davis-Daly	1½
Eagle & Blue Bell	1 3/16
Houghton Copper	1½
Iron Cap Cop., pf.	5½
Mexican Metals	.26
Mojave Tungsten	5½
Nat. Zinc & Lead	1½
Nevada-Douglas	.90
New Baltic	2
New Cornelia	13
Ohio Copper	.14
Oneco	1
Raven Copper	‡.18
Rex Cons.	.14
Rilla	.35
United Verde Ext.	29½

‡Last Quotations.

Monthly Average Prices of Metals

SILVER

Month	New York			London		
	1914	1915	1916	1914	1915	1916
January	56.572	48.855	56.775	26.553	22.731	26.960
February	57.506	48.477	56.755	26.573	22.753	26.975
March	58.067	50.241	57.935	26.788	23.708	27.597
April	58.519	50.250	64.415	26.958	23.709	30.662
May	58.175	49.915	74.269	26.704	23.570	35.477
June	56.471	49.034	.....	25.948	23.267	.....
July	54.678	47.519	.....	25.219	22.597	.....
August	54.344	47.163	.....	25.979	22.780	.....
September	53.290	48.680	.....	24.260	23.591	.....
October	50.654	49.385	.....	23.199	23.925	.....
November	49.082	51.714	.....	22.703	25.094	.....
December	49.375	54.971	.....	22.900	26.373	.....
Year	54.811	49.684	.....	25.314	23.675	.....

New York quotations cents per ounce troy, fine silver; London, pence per ounce, sterling silver, 0.925 fine.

COPPER

Month	New York		London			
	Electrolytic		Standard		Electrolytic	
	1915	1916	1915	1916	1915	1916
Jan.	13.641	24.008	60.756	88.083	65.719	116.167
Feb.	14.394	26.440	63.494	102.667	*	133.167
Mar.	14.787	26.310	66.152	107.714	*	136.000
April	16.811	27.895	75.096	124.319	*	137.389
May	18.506	28.625	77.600	135.457	*	152.522
June	19.477	.....	82.574	.....	95.333	.....
July	18.796	.....	76.011	.....	91.409	.....
Aug.	16.941	.....	68.673	.....	82.333	.....
Sept.	17.502	.....	68.915	.....	85.250	.....
Oct.	17.686	.....	72.601	.....	88.000	.....
Nov.	18.627	.....	77.744	.....	93.273	.....
Dec.	20.133	.....	80.773	.....	100.43	.....
Year	17.275	.....	72.532	.....	.....	.....

TIN

Month	New York		London	
	1915	1916	1915	1916
January	34.260	41.825	156.550	175.548
February	37.415	42.717	176.925	181.107
March	48.426	50.741	180.141	193.609
April	47.884	51.230	166.225	199.736
May	38.790	49.125	162.675	196.511
June	40.288	.....	167.636	.....
July	37.423	.....	167.080	.....
August	34.389	.....	151.440	.....
September	33.125	.....	152.625	.....
October	33.080	.....	151.554	.....
November	39.224	.....	167.670	.....
December	38.779	.....	167.000	.....
Av. year	38.590	.....	163.960	.....

LEAD

Month	New York		St. Louis		London	
	1915	1916	1915	1916	1915	1916
January	3.729	5.921	3.548	5.826	18.606	31.167
February	3.827	6.246	3.718	6.164	19.122	31.988
March	4.053	7.136	3.997	7.375	21.883	34.440
April	4.221	7.630	4.142	7.655	21.094	34.368
May	4.274	7.463	4.182	7.332	20.347	32.967
June	5.932	.....	5.836	.....	25.170	.....
July	5.659	.....	5.531	.....	24.611	.....
August	4.656	.....	4.520	.....	21.946	.....
September	4.610	.....	4.490	.....	23.151	.....
October	4.600	.....	4.499	.....	23.994	.....
November	5.155	.....	5.078	.....	26.278	.....
December	5.355	.....	5.266	.....	28.807	.....
Year	4.673	.....	4.567	.....	22.917	.....

SPELTER

Month	New York		St. Louis		London	
	1915	1916	1915	1916	1915	1916
Jan.	6.386	16.915	6.211	16.745	30.844	89.810
Feb.	8.436	18.420	8.255	18.260	39.819	97.762
Mar.	8.541	16.846	8.360	16.676	44.141	95.048
April	10.012	16.695	9.837	16.525	49.888	99.056
May	14.781	14.276	14.610	14.106	68.100	94.217
June	21.208	.....	21.038	.....	100.614	.....
July	19.026	.....	18.856	.....	97.250	.....
Aug.	12.781	.....	12.611	.....	67.786	.....
Sept.	13.440	.....	13.270	.....	67.841	.....
Oct.	12.800	.....	12.596	.....	66.536	.....
Nov.	15.962	.....	15.792	.....	88.409	.....
Dec.	15.391	.....	15.221	.....	89.400	.....
Year	13.230	.....	13.054	.....	67.553	.....

New York and St. Louis quotations, cents per pound, London, pounds sterling per long ton. * Not reported.

PIG IRON IN PITTSBURGH

Month	Bessemer‡		Basic‡		No. 2 Foundry	
	1915	1916	1915	1916	1915	1916
January	$14.59	$21.60	$13.45	$18.78	$13.90	$19.70
February	14.55	21.16	13.45	18.93	13.90	19.51
March	14.55	21.81	13.45	19.20	13.95	19.45
April	14.55	21.65	13.45	18.95	13.95	19.45
May	14.61	21.78	13.60	19.11	13.83	19.58
June	14.70	.....	13.67	.....	13.77	.....
July	14.94	.....	13.91	.....	13.68	.....
August	16.01	.....	15.31	.....	14.75	.....
September	16.86	.....	15.95	.....	15.70	.....
October	16.95	.....	15.96	.....	15.80	.....
November	17 57	.....	16.47	.....	17.20	.....
December	19.97	.....	18.44	.....	18.95	.....
Year	$15.82	.....	$14.76	.....	$14.95	.....

‡As reported by W. P. Snyder & Co.

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